before discharge. Details of the aeration process will be given in a subsequent report. This treatment will probably not be necessary until the proposed drainage system has been developed to at least one-half of its ultimate capacity. After that time it will be necessary to employ the aeration process only during certain of the summer months, and at ultimate development such employment will probably not exceed four months of the year. These facts have an important bearing on the consideration of the ultimate cost of treatment.

140 The discharge into Little Neck Bay is necessarily into shoal water near the head of a land-locked bay in which practically the only circulation is that due to tidal flow. It is therefore impossible to make any accurate calculations of the dilution factor, but purification will evidently be required. We recommend at the start effective fine screening, a short period of sedimentation, and forced aeration. Our recommendation of the latter process is based upon experimental work which we have conducted during the summer at Brooklyn and at Boston. This work is not yet completed, but has gone far enough to enable us to state that in situations similar to the one under discussion an important reduction in the putrescibility of the sewage can be obtained in this manner and at reasonable costs.

The three outlets along the shore front of the Rockaway Section will each be carried about 1,000 feet off shore into water having a mean depth of 15 feet. Experience elsewhere, notably at Asbury Park and Ocean Grove, has indicated that with suitable provision for the removal of the grosser suspended matter, such a method of disposal may be used without any resulting nuisance. We recommend disposal work at these points, consisting of screening and a short period of detention in hydrolytic tanks, so designed as to clarify the sewage and give a maximum of liquefying action with a minimum of anaerobic putrefaction.

Very respectfully,

W. M. BLACK.
EARLE B. PHELPS.

(Here follows map marked page 141, Complainants' Exhibit No. 136.)

142 *Special Report on the Richmond Drainage District.*

Submitted to the Board of Estimate and Apportionment March 9, 1911.

143 CHIEF ENGINEER'S OFFICE,
BOARD OF ESTIMATE AND APPORTIONMENT,
CITY OF NEW YORK, March 4, 1911.

Hon. William J. Gaynor, Mayor, Chairman of the Board of Estimate and Apportionment:

SIR: Herewith is transmitted the report of Colonel William M. Black, U. S. A., and Professor Earle B. Phelps, bearing date of February 15, 1911, in the matter of the locations which might properly be selected for the discharge of sewage from the entire Borough of Richmond.

This report has been prepared pursuant to the instructions given by the Board in 1909, under which Colonel Black was requested to advise concerning the method which, in his judgment, might properly be adopted in order to most advantageously use the harbor waters for the removal of sewage, and has been prepared along the same lines as were followed in investigating the Corona, Flushing, and Jamaica districts of the Borough of Queens, in each of which sections it was found necessary to outline a general plan for the drainage of the entire area affected in order to establish the practicability of using the points selected for outlet.

The report now submitted completes the investigation in so far as it relates to the portions of the City for which no complete drainage plan has yet been prepared.

The investigation was also made to include a study of the circulation of fresh and polluted water in the harbor, with a view of determining the amount of sewage which could properly be admitted in various sections, together with the results of experimental work concerning a new process of purification which it was believed might be employed with advantage. The results of the latter investigation are contained in another communication which will be made the subject of a separate report, this completing the entire work originally contemplated.

In this report it is pointed out that about 63 per cent. of the entire area of the Borough of Richmond is located on the northwesterly side of the backbone of the island and drains naturally into the Arthur Kill and the Kill von Kull, and that of the 36 miles of coast line about one-half borders upon the kills, neither of which can be considered as available for the discharge of crude sewage. It is also pointed out that the five miles of coast line bordering the upper bay are similarly unavailable for such use owing to the pollution to which they are already subjected, and that of the remaining thirteen miles having frontage upon the lower bay a considerable portion is unavailable for the discharge of sewage owing in part to the shallow

depth, and in part to the tidal circulation which would result in the return of discharged sewage to the bathing beaches. These conditions leave only the upper portion of the lower bay in the vicinity of the Narrows and the southerly portion of the island as the only sections along the coast line suited for the use under consideration unless purification is resorted to. The plan which has been outlined is intended to meet these conditions in so far as practicable and provides for the collection and discharge of sewage at seven points.

144 Two of these points are located in the vicinity of Fort Wadsworth, here outletting into the deep waters of the Narrows. At these two points there will be concentrated more than one-half of the total sanitary flow for the Borough, this being accomplished by bringing a portion of the sewage from the westerly water-shed southwardly through the gap at Richmond, thence returning along the easterly slope of the island.

The five remaining points are located respectively at Great Kills, Seguine's Point and Red Bank on the southerly side of the island, and at Lake's Island and Bloomfield on the Arthur Kill. At the last two mentioned points purification by sedimentation and forced aeration will be required.

It has been assumed that the island will have a population representing a density of about 25 persons per acre and that the dry weather flow will be equivalent to a water consumption of 125 gallons per capita per day, of which one-half would be discharged into the sewers in eight hours. In determining the size of sewers for the sanitary flow an allowance has been made for a seepage of ground water at a uniform rate of 0.003 cubic feet per second per acre. It has been assumed that the flow in the sewers will have a velocity of three feet per second, and that a minimum of six feet of cover will be provided.

In the studies no provision has been made for the removal of the storm flow, it being understood that this study was in no way connected with the investigation desired by the Board.

Owing to the low elevation of many of the areas affected it has been deemed necessary to make provision for eleven pumping stations at which the sewage would be elevated through heights varying from 6 feet upwards to 42 feet, requiring an aggregate of 525 horse-power. Provision is also made for six force mains having an aggregate length of about 18,900 feet.

The report includes tables giving the essential elements of the system as planned, which is also shown upon a general map which accompanies the report.

It is understood that owing in part to the absence of data on which a complete plan could be prepared, and in part to the fact that this investigation was intended to be limited simply to such work as was involved in establishing the practicability of carrying the drainage to the points selected for outlet that the plan is not offered as of other than of a suggestive character and that a more or less radical revision may be necessary in many particulars.

I would recommend that a copy of this report and of the accompanying map be transmitted to the President of the Borough of

Richmond with the suggestion that he be asked to give them careful consideration in the preparation of the drainage plans for this district.

Respectfully,

NELSON P. LEWIS,
Chief Engineer.

145 February 15, 1911.

Mr. Nelson P. Lewis, Chief Engineer, Board of Estimate and Apportionment, New York City, New York:

SIR: In connection with our general studies of the sewerage problem of certain portions of Greater New York, we submit herewith a report upon that portion of our work which deals with the Borough of Richmond, and which, in accordance with our previous practice, we will term "The Richmond Drainage District."

Physical Features.

Physically, the Borough of Richmond, or Staten Island, is not well suited for an economical design of a comprehensive drainage system. Although presenting bold slopes and favorable grades in many cases, in others, flat, marshy tracts render the collection of sewage by gravity extremely difficult. Again, the ridges and hills which produce the favorable slopes in some places, offer a most effective barrier to the outlet of the sewage when once collected, except by long detours and consequent loss of elevation, or by still more expensive processes of tunneling.

The island drains naturally in two directions; to the east, or towards the Lower Bay, where tidal circulation is excellent, the water is constantly renewed by influx from the unpolluted supply of the Atlantic Ocean, and the capacity for sewage reduction is almost unlimited; and to the west, or towards the Arthur Kill, where tidal circulation is poor, the water merely rising and falling without greatly changing on each tide, and where it is reported that in parts pollution from the various New Jersey rivers has already passed the stage of a nuisance.

The divide between these two watersheds consists of a pronounced ridge, running the entire length of and forming the backbone of the island. At the north end this ridge rises abruptly to a height of 200 feet and over, continuing south with steep slopes on either side, and increasing gradually in elevation to over 400 feet at a distance of about four miles from the upper end. Two miles farther south the ridge drops suddenly to the lowest point of its entire length, and rises again, but more gradually, forming a gap at an elevation of about 50 feet. From this gap, which plays an important part in the design hereinafter proposed, the ridge continues irregularly to the southern end of the island, averaging only about 100 feet in height, and nowhere rising above 150 feet.

The total length of the island is about thirteen miles, and its greatest width about eight miles. The area is over 57 square miles,

or 36,623 acres, of which 13,584 acres, or 37 per cent., lie in the eastern watershed, and 23,039 acres, or 63 per cent., in the western watershed, which drains naturally into the already polluted kills.
146 In the upper part of the island, and bordering upon the Arthur Kill, are extensive swamp areas, aggregating about 6,461 acres below the 10-foot contour.

The length of coast line is 36 miles, of which 18 miles, or 50 per cent., border upon the kills, and are not available for the discharge of untreated sewage, 5 miles upon the Upper Bay, which is already greatly burdened by the sewage from the East and Hudson Rivers and the Kill von Kull, and will soon feel the effects of the New Passaic Valley outlet, which leaves barely 13 miles, or 36 per cent. of the total perimeter, bordering upon the Lower Bay, where raw sewage may be safely discharged. Again, certain points only of this coast are available for discharge, as the water is shoal and prevents good tidal circulation in a number of places. At the Narrows, discharge is safe if carried out to deep water in the channel; below this, at the beaches, everything discharged returns upon the shore, so that no outfalls are permissible in this vicinity. The lower half of this coast, however, embracing the stretch between Great Kills and the southern extremity of the island, is shown by the United States Coast Survey charts to have a channel parallel to the shore, into which sewage may be discharged with a reasonable certainty of its being carried away by the tidal currents.

Division Into Drainage Areas.*

The island is divided into nine main divisions, lettered A to I, inclusive, as explained in the succeeding paragraphs, and each division is further divided into several drainage areas, numbered 1 to 85, inclusive, for the entire island. The locations of these areas are as follows:

Division A, Areas 1-9.

This comprises the area lying on the western slope of the ridge and tributary to the Kill von Kull, extending westward to the low land bordering upon the Arthur Kill.

Area 1 comprises Districts 17 (*a*), 18 (*a*), and 19 (*a*) of the Sewer Department.

Area 2 comprises the valley extending inland from Port Richmond.

Area 3 is composed of that section of the north shore extending from Snug Harbor westward to Port Richmond.

NOTE.—Areas 1-3 require a low-level system, the flow from which will be concentrated at the Shore road (Richmond terrace) and Columbia street, and pumped through a force-main along the latter to the gravity Interceptor at Post avenue.

Area 4 is a large tract lying upon the slope of the ridge, and extending from the crest down to the 50-foot contour.

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* See map of Richmond Drainage District following p. 182.

Areas 5 and 6 occupy the head of the valley of Clove Brook, extending to the crest of the ridge.

Area 7 occupies the remaining portion of the valley around Richmond Lake and lying above the 40-foot contour.

Area 8 lies between Area 3 on the north and Area 6 on the south.

Area 9 lies at the junction of the line of the ridge with the shore.

Division B, Areas 10-17.

This comprises the area lying on the eastern slope of the ridge, above the Narrows, and tributary to the Upper Bay.

147 Areas 10, 11 and 12, occupy the extreme northeast corner of the island, 11 and 12 comprising Districts 1 (*a*) and 1 (D), respectively, of the Sewer Department.

Areas 13, 14 and 15 occupy the valley extending from Tompkinsville inland to the Fingerboard road.

Area 16 borders upon the Upper Bay, just above the Narrows.

Area 17 comprises the western shore of the Narrows, and includes the military reservation of Fort Wadsworth, which may at some future date connect with the sewerage system of the borough.

Division C, Areas 18-33.

This comprises the area lying on the western slope of the ridge, above the 50-foot contour, between Willow Brook on the north and Huguenot avenue on the south.

Areas 18, 19, 20 and 21 lie upon the western slope of the ridge, above the Gap, and in the order named from Willow Brook to Richmond Creek.

Areas 22 and 23 occupy the valley just west of the ridge and extending north from the Gap.

Areas 24 to 33 lie in an irregular semi-circle between the summit of the ridge and the low land bordering upon the Fresh Kills.

Area 24 lies at the western extremity of this semi-circle, near the Arthur Kill, and Area 33 at the eastern end, just south of the Gap.

Division D, Areas 34-46.

This comprises that area lying on the eastern slopes of the ridge, above the 40-foot contour, between the Narrows on the north and Great Kills on the south, including the low land back of South Beach.

Areas 34 and 35 occupy the eastern slope of the ridge, adjacent to the Gap, and between the summit and the low land around Great Kills.

Area 36 occupies the valley east of the ridge and north of the Gap.

Area 37 includes the village of New Dorp, lying at the mouth of the valley comprising Area 36.

Areas 38 and 39 lie upon the eastern slope of the ridge, back of Grant City.

Areas 40, 41 and 42 comprise the low land bordering upon the Lower Bay and extending from South Beach on the north to Elm Tree Beacon on the south.

Areas 43, 44, 45 and 46 lie, in the order named, upon the southern slope of the spur ridge extending from the main ridge to the Narrows.

Division E, Areas 47-51.

Areas 47 and 48 occupy the low land composing the western shore of Great Kills Bay.

Area 49 occupies the low ground extending from the head of Great Kills Bay back to the 50-foot contour.

Area 50 includes the low land north of Great Kills Bay and bordering upon the Lower Bay.

Area 51 constitutes the small peninsula which forms the eastern shore of Great Kills Bay.

148 Division F, Areas 52-58.

Areas 52, 53, 54 and 55 extend, in the order named, along the shore of the Lower Bay, from Great Kills on the north to Seguine's Point on the south.

Areas 56 and 57 occupy the head, and Area 58 the mouth, of the valley of Lemon Creek, which extends inland from the head of Princes Bay.

Division G, Areas 59-68.

This comprises the entire southern end of the island.

Areas 59, 60, 61, and 62 lie upon the shore of Arthur Kill, extending south from Smoking Point to Mill Creek.

Area 63 lies between the areas bordering upon Arthur Kill, and the summit of the ridge, north of Mill Creek.

Area 64 occupies the low land bordering upon the Arthur Kill, south of Mill Creek.

Area 65 lies south of Mill Creek, between the summit of the ridge and Area 64.

Area 66 lies upon the shore of Princes Bay.

Area 67 occupies the southern extremity of the island.

Area 68 lies upon the eastern slope of the ridge, about midway between Princes Bay and the southern extremity of the island.

Division H, Areas 69-79.

This comprises the low area tributary to the Fresh Kills and Arthur Kill.

Area 69 lies upon either side of Richmond Creek, just west of the Gap.

Areas 70, 71 and 73 occupy the south bank of Richmond Creek, extending, in the order named, from Area 69 towards the Arthur

Kill, and Area 72 lies between Area 71 and the summit of the ridge.

Area 74 lies upon the shore of the Arthur Kill, south of Fresh Kills.

Areas 75, 76 and 77 occupy the low ground east of Fresh Kills Creek, lying below the 50-foot contour, extending, in the order named, from the head of the creek to the fork of Fresh Kills.

Area 78 lies on the coast of Arthur Kill, north of Fresh Kills.

Area 79 comprises Lakes Island, at the mouth of Fresh Kills.

Division I, Areas 80-85.

Areas 80 and 81 occupy the coast of Arthur Kill, opposite the mouth of the Rahway River, New Jersey, and Pralls Island, respectively.

Areas 82 and 83 occupy the valley of Old Place Creek.

Area 84 occupies the extreme northwestern corner of the island, at the opening of the Arthur Kill into Newark Bay.

Area 85 lies upon the shore of Arthur Kill, between the mouth of Old Place Creek on the north, and Pralls Island on the south.

The acreage and estimated future populations of these 85 drainage areas are tabulated below. The total area of the district is seen to be 36,623 acres and the total estimated future population 915,575.

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Area.	Acres.	Assumed future "Equivalent population."	
		Per acre.	Total.
1	336	25	8,400
2	1,085	25	27.125
3	339	25	8.475
4	1,235	25	30,875
5	555	25	13.875
6	311	25	7.775
7	474	25	11,850
8	603	25	15.075
9	411	25	10,275
10	277	25	6.925
11	108	25	2,700
12	95	25	2,375
13	298	25	7.450
14	430	25	10,750
15	592	25	14.800
16	453	25	11.325
17	411	25	10,275
18	736	25	18,400
19	644	25	16,100
20	215	25	5.375
21	408	25	10,200
22	615	25	15,375
23	458	25	11,450
24	261	25	6,525
25	265	25	6,625
26	157	25	3,925
27	365	25	9,125
28	711	25	17,775
29	312	25	7,800
30	341	25	8.525

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Area.	Acres.	Assumed future "Equivalent population." Per acre.	Total.
31	405	25	10,125
32	107	25	2,675
33	180	25	4.500
34	250	25	6.250
35	294	25	7 350
36	482	25	12.050
37	307	25	7,675
38	98	25	2,450
39	71	25	1.775
40	642	25	16,050
41	499	25	12.475
42	681	25	17.025
43	398	25	9.950
44	301	25	7,525
45	238	25	5,950
46	133	25	3,325
47	279	25	6,975
48	302	25	7.550
49	511	25	12,775
50	739	25	18.475
51	161	25	4,025
52	440	25	11,000
53	342	25	8,550
54	498	25	12,450
55	695	25	17.375
56	545	25	13.625
57	265	25	6,625
58	552	25	13,800
59	713	25	17,825
60	471	25	11.775
61	198	25	4.950
62	322	25	8,050
63	436	25	10,900
64	291	25	7.275
65	193	25	4.825
66	388	25	9,700
67	339	25	8,475
68	470	25	11.750
69	340	25	8,500
70	318	25	7,950
71	87	85	2,175
72	324	25	8,100
73	186	25	4,650
74	755	25	18,875
75	654	25	16,350
76	695	25	17,375
77	568	25	14.200
78	915	25	22,875
79	120	25	3,000
80	408	25	10,200
81	630	25	16,750
82	817	25	20,425
83	606	25	15,150
84	845	25	21,125
85	618	25	15,450
Total	36,623	..	915,575

General Scheme of Sewerage for the District.

The proposed design takes advantage of the most favorable physical features, and attempts to reduce to a minimum the cost of overcoming the difficulties.

Items which add greatly to the expense of a sewer system are: pumping, purification, detours involving great length of line, and tunneling. In order to concentrate at points allowing safe discharge, a certain amount of pumping is necessary, but this item has been kept as low as possible consistent with the avoidance of outfalls where purification would be required, and no lifts are here contemplated on the main lines, except where a force-main outfall must be installed, so that, generally, the amounts lifted, as well as the lifts themselves, are small, and may be served by automatic pumping stations.

Where pumping to a point of safe discharge would cost in excess of the cost of partial purification, small works are contemplated to purify to such extent as will render discharge into the Arthur
151 Kill unobjectionable. Only such degree of treatment is required as will produce an effluent of sufficient stability to delay putrefaction until the larger reservoir of the Lower Bay is reached.

At the main points of discharge, at the Narrows and in the Lower Bay, no purification is considered necessary.

Some long detours will have to be made, to secure favorable grades and to avoid the necessity of tunneling, which expedient will not be necessary in this design. The detours which are required to secure an outlet at the Gap will be less expensive than a tunnel through the ridge at any other point, as the distance between low ground on either side is considerable except at the Gap.

Divisions A and B, Areas 1-17.

The proposed design is as follows:

The area west of the ridge and tributary to the Kill von Kull, back to the low land bordering upon the Arthur Kill, is drained by a gravity interceptor, No. 1, along the north shore, the lower ground being served by a low-level system, whose flow is lifted by pumping to the level of Interceptor I. This interceptor encircles the northern point of the island, and serves also that area east of the ridge and above the Narrows which is tributary to the Upper Bay. The Outfall is just above Quarantine, at the foot of Pennsylvania avenue. The area tributary to this system is 8,013 acres, and the estimated maximum discharge at the outfall is 81.95 second-feet.

Divisions C and D, Areas 18-46.

The area lying on the western slope of the ridge, above the fifty-foot contour, and extending from about Willow Brook on the north to Huguenot avenue on the south, is served by two gravity inter-

ceptors, Nos. II and III, which unite at the Gap. Interceptor II serves the area north of the junction, and Interceptor III that to the south. After the junction, the interceptor, now known as No. IV, crosses the ridge at the Gap and serves that portion of the eastern slope between Great Kills and the Narrows which lies above about the forty-foot contour. The low-lying area back of and including South Beach is also served by this system, the flow being lifted through a force-main to Interceptor IV, in order to prevent the fouling of the beaches which would result were the outfall placed in this vicinity. The final discharge is located just below the Narrows, in deep water off shore.

The area tributary to this system is 10,574 acres, and the estimated maximum flow at the outfall is 108.18 second-feet.

Division E, Areas 47-51.

The low-lying area in the vicinity of Great Kills Bay is concentrated by gravity at a point near the head of the Bay, and pumped out to sea.

The tributary area is 1,992 acres, and the discharge 20.39 second-feet.

Division F, Areas 52-58.

The area on the eastern slopes of the ridge, lying between Great Kills on the north and Princes Bay on the south, most of which has a good elevation, is drained by Interceptor V to a concentration point at Seguine's Point, near the head of Princes Bay, and pumped Seaward.

The tributary area is 3,337 acres, and the discharge 34.14 second-feet.

152 Division G, Areas 59-68.

The area on the western slopes of the ridge, lying between Smoking Point on the north and the southern extremity of the island, is concentrated by Interceptor VI, with one relay lift for that portion north of Kreischerville, at a pumping station on Mill Creek, whence it is pumped through a force-main to a continuation of the gravity interceptor at the summit of the ridge. From this point the discharge is by gravity into the deep water off shore.

The area tributary to the gravity system of this division is 2,624 acres, and the maximum discharge is 26.84 second-feet.

The low level portion of this Division consists of the area lying on the eastern slope of the ridge, between Princes Bay and the southern end of the island, whose flow is collected by gravity at Red Bank, and lifted to the gravity outfall, by pumping.

The area tributary to this low level system is 1,197 acres, and the discharge is 12.25 second-feet.

The total area of Division G is 3,821 acres, and the discharge is 39.09 second-feet.

Division H, Areas 69-79.

The low, marshy area adjacent to the Fresh Kills, and tributary to the Arthur Kill, is served by two interceptors, Nos. VII and VIII, draining, with one relay lift in each, the areas south and north, respectively, of Fresh Kills and Richmond Creek. Both interceptors concentrate at the same point on Lakes Island, at the mouth of Fresh Kills, where the sewage will be purified sufficiently to permit its discharge into Arthur Kill without nuisance.

The tributary area is 4,962 acres, the discharge 50.75 second-feet.

Division I, Areas 80-85.

The flow from the low area occupying the northwestern corner of the island, and tributary to the Arthur Kill, will be concentrated by a gravity interceptor, No. IX, at a point on the shore of the Arthur Kill, north of Pralls Island, where it will be partially purified and finally discharged into Arthur Kill.

The tributary area is 3,924 acres, and the discharge 40.13 second-feet.

Trunk sewers are designated in general by the number of the area served. Their locations are as given in the following summary a study of which will be facilitated by reference to the accompanying map. The division lines between areas are indicated by heavy dotted lines, the sewers in solid red lines. Other devices used are sufficiently explained in the legend. Contours are at 20-foot intervals.

Division A.

1. From 1,000 feet west of South avenue, east along Shore road (Richmond terrace), to junction with Trunk 2 at Lafayette avenue.

2. From near Richmond turnpike, north, nearly parallel to Port Richmond road and Richmond avenue, to junction with Trunk 1 at Shore road (Richmond terrace).

1-2. Along Shore road (Richmond terrace), from Lafayette avenue to Columbia Street Pumping Station.

153 3. From Bard avenue, west along Richmond terrace to Columbia Street Pumping Station.

1-2-3. Columbia Street Force-main. From Columbia Street Pumping Station, at Richmond terrace, south along Columbia street to Interceptor I. at Post avenue.

4. From near Ocean Terrace road, at summit of the ridge, west down valley of stream to about 50-foot contour; thence along latter to junction with Columbia Street Force-Main at Columbia street and Post avenue.

5. From near summit of ridge, north along valley of stream to junction with Trunk 6 at Schœnian Pond.

5-6. From Junction of Trunks 5 and 6, north along valley of Clove Brook to Richmond Lake.

7. No trunk has been designed for Area 7, the flow from which will be considered as entering Trunk 5-6 at Richmond Lake.

5-6-7. From Richmond Lake, north along valley of Clove Brook to Interceptor I at Post avenue and Columbia street.

8. From near summit of ridge, northwest along valley of stream, to Castleton avenue, along Castleton avenue, Rement avenue to Interceptor I at Henderson avenue.

9. From summit of ridge, north along Lafayette avenue to Interceptor I. at Richmond terrace.

Division B.

10. From near summit of ridge, north along Richmond turnpike and Jersey street to Interceptor I. at Richmond terrace.

11. No trunk has been designed for Area 11, as this area is already sewered, and its trunk will be intercepted at Church street and Richmond terrace.

12. No trunk has been designed for Area 12, as this area is already sewered, and its trunk will be intercepted at Arietta street and Central avenue.

13. From junction of Fingerboard and Richmond roads, north along valley of stream to De Kalb avenue.

14. No trunk has been designed for Area 14, the flow from which will be considered as entering Trunk 13 at De Kalb avenue.

13-14. From De Kalb avenue, north along Danube avenue, Simonson place and Targee street to Laurel avenue.

15. No trunk has been designed for Area 15, the flow from which will be considered as entering Trunk 13-14 at Targee street and Laurel avenue.

13-14-15. From Targee street, along Laurel avenue, Gordon, Broad and Canal streets to Interceptor I. at Riker street.

16. From Grasmere Lake, north and east to Interceptor I. on Willow avenue.

17. From high ground back of Fort Wadsworth, east and north along Fingerboard road and New York avenue to junction with Interceptor I. at Pennsylvania avenue.

Division C.

18. From about 300-foot contour, on Manor road, west down valley of Willow Brook to near Willow Brook road; thence southwest to Interceptor II. at Rockland avenue, on 50-foot contour.

154 19. From about 220-foot contour, at Manor road, west down valley of Springville Creek to junction with Trunk 18 at 50-foot contour.

20. From about 140-foot contour, near Forest Hill avenue, west and south to Interceptor II, south of Richmond Hill road.

21. From about 130-foot contour, near crest of small ridge, south along valley of stream to Interceptor II.

22. From 300-foot contour, near Egbert avenue, south down valley of Richmond Creek to 100-foot contour on Saw Mill road.

23. No trunk has been designed for Area 23, the flow from which will be considered as entering Trunk 22 at the 100-foot contour on Saw Mill road.

22-23. From 100-foot contour, on Saw Mill road, south along valley of Richmond Creek, to Interceptor II. at Richmond.

24. From about 100-foot contour, near Huguenot avenue, north and east to junction with Trunk 25 at 50-foot contour, north of Washington avenue.

25. From 120-foot contour, along Washington avenue and valley of small stream to Interceptor III. at 50-foot contour.

26. From near Fresh Kills road, south along Greenridge avenue to Interceptor III.

27. From about 140-foot contour, near Huguenot avenue, east and north along valley of small stream to junction with Trunk 27-28 at Washington avenue.

28. No trunk has been designed for Area 28, the flow which will be considered as entering Trunk 27 at Washington avenue.

27-28. From junction of Trunks 27 and 28, east and north to Interceptor III.

29. From 80-foot contour, Woods of Arden, northeast, parallel to railroad to Wilson avenue; thence west along valley of stream to junction with Trunk 30 at about 50-foot contour.

30. From 60-foot contour, at Gifford's, south to Trunk 29.

29-30. From junction of Trunks 29 and 30, along valley of small stream to Interceptor III.

31. From 60-foot contour, north of Gifford's lane, west to Interceptor III.

32. From 80-foot contour, north along valley of small stream to Interceptor III.

33. From near summit of ridge, south of Gap, to Interceptor IV. at Gap.

Division D.

34. From Great Kills north, parallel to railroad, to junction with Trunk 35 at Clark avenue.

35. From 80-foot contour, east on Clark avenue to Trunk 34.

34-35. From junction of Trunks 34 and 35, north, parallel to railroad, to Interceptor IV. at Amboy road.

36. From 340-foot contour, on Todt Hill road, south along valley of creek to junction with Trunk 37 at Sixth street and Elm avenue, New Dorp.

155 37. From 140-foot contour, near New Dorp Beacon, east and south down valley of stream, along Grand avenue, Richmond road, Amboy road, Ocean avenue and Sixth street to Trunk 36 at Elm avenue.

36-37. From junction of Trunks 36 and 37 at Elm avenue, along prolongation of Elm avenue to Interceptor IV. on prolongation of Tenth street.

38. From Central avenue, along Richmond road and Barton avenue to Interceptor IV. at 30-foot contour.

39. From Jackson avenue, north along Richmond road, and east along Liberty avenue to Interceptor IV. at 30-foot contour.

40. From about 20-foot contour, near New Dorp lane, north and east to junction with Trunk 41 at New Creek.

41. From near railroad, Dongan Hills, east to Trunk 40.

40-41. From junction of Trunks 40 and 41, north to Sea View avenue Pumping Station.

42. From South Beach, south, parallel to shore, to Sea View Avenue Pumping Station.

40-41-42. Sea View Avenue Force-Main. From Sea View Avenue Pumping Station west along Sea View avenue to Interceptor IV. at 30-foot contour.

43. From 300-foot contour, near Ocean Terrace road, at summit of ridge, east down valley of stream to Interceptor IV. at 30-foot contour.

44. From 100-foot contour, near Grasmere, south along valley of stream and Parkinson avenue to Interceptor IV.

45. From 100-foot contour, on Fingerboard road, east and south along Fingerboard road and Sand Lane road to Interceptor IV.

46. From about 100-foot contour, south along Sea avenue to Interceptor IV. at Old Town avenue.

Division E.

47. From 60-foot contour, on Nelson avenue, southeast along Nelson avenue, nearly to shore of Great Kills Bay; thence following shore to junction with Trunk 48.

48. From 60-foot contour, along valley of small stream to Trunk 47, near shore of Great Kills Bay.

47-48. From junction of Trunks 47 and 48, northeast to junction with Trunk 49 at Mill Pond, near head of Great Kills Bay.

49. From 40-foot contour, near railroad at Courthouse, east and south along stream to Trunk 47-48 at Mill Pond.

47-48-49. From junction of Trunk 47-48 with Trunk 49, at Mill Pond, east to Great Kills Pumping Station.

50. South along shore from Elm Tree Beacon to Great Kills Pumping Station.

51. North along Great Kills Peninsula to Great Kills Pumping Station.

47-51. Outfall Section. From Great Kills Pumping Station, southeast to water 12 feet deep, 5,000 feet off shore.

Division F.

52. From 60-foot contour, opposite mouth of Great Kills Bay, south to shore, following shore southwest to junction with Trunk 53 at Barclay avenue.

156 53. From 60-foot contour, near Amboy road, south along small stream, parallel to Barclay avenue to junction with Trunk 52.

54. From 80-foot contour, near railroad, following valley of small

stream south to junction with Interceptor V. at Latourette's Pond, near shore.

55. From 100-foot contour, south along valley of stream, to junction with Interceptor V. at Wolfs Pond, near shore.

56. From 120-foot contour, near Wood Row, west and south to junction with Trunk 57, at Maguire avenue, near fork of Lemon Creek.

57. From 100-foot contour, west and south to junction with Trunk 56, at Maguire avenue, near fork of Lemon Creek.

56-57. From junction of Trunks 56 and 57, south and east along valley of Lemon Creek, to a point nearly opposite Findlay avenue.

58. No trunk has been designed for Area 58, the flow from which will be considered as entering Trunk 56-57 at a point opposite Findlay avenue.

56-57-58. From bend in Lemon Creek, opposite Findlay avenue, along valley of Lemon Creek, to Seguine's Point Pumping Station.

Division G.

59. From Rossville, west and south along shore of Arthur Kill to Kreischerville Relay Pumping Station, at junction with Trunk 60, at mouth of stream opposite Boynton Beach, New Jersey.

60. From 100-foot contour, near Pleasant avenue, west along valley of stream to Kreischerville Relay Pumping Station, at junction with Trunk 59.

61. From 100-foot contour, west to south end of Kreischerville Force-main.

62. From 80-foot contour, south to Interceptor VI., near Mill Creek.

63. From about 100-foot contour, south of Sharrott's road, south and west to Interceptor VI., at junction with Trunk 62.

64. From near Hopkins avenue, Tottenville, north along shore of Arthur Kill to Mill Creek Pumping Station.

65. From 60-foot contour, near summit of ridge, along valley of Mill Creek to Mill Creek Pumping Station.

66. From 40-foot contour, near summit of ridge, south to shore of Prince's Bay; following shore southwest to Red Bank Pumping Station.

67. From near Bay Cliff Lake, at summit of ridge, south to shore, near southern extremity of island; northeast along shore to junction with Trunk 68 at Central avenue.

68. From summit of ridge, near 60-foot contour, south along Central avenue, to junction with Trunk 67 at shore.

67-68. From Central avenue, northeast along shore to Red Bank Pumping Station.

Division H.

69. From near Fresh Kills road, following line of Richmond Creek, to Richmond Creek Pumping Station, near Fresh Kills Bridge.

70. From 10-foot contour, near Eltingville road, east and north to Richmond Creek Pumping Station.

157 71. From 20-foot contour, near Greenridge avenue, and Fresh Kills road, northeast to west end of Richmond Creek Force-main, near bend in Richmond Creek.

72. From 40-foot contour, near Washington avenue, north along valley of small stream, to junction with Trunk 73, about 2,000 feet from Fresh Kills.

73. From spur of ridge, west of Trunk 72.

72-73. From junction of Trunks 72 and 73, north to Interceptor VII., near fork of Fresh Kills.

74. From 40-foot contour, near Fresh Kills road, and Huguenot avenue, north, parallel to shore of Arthur Kill, to junction with Interceptor VII. on Fresh Kills, opposite Lake's Island.

75. From about 40-foot contour, at Willow Brook, following the Brook and east shore of Fresh Kills Creek, west and south to junction with Trunk 76 at mouth of Springville Creek.

76. From near 40-foot contour, on Rockland avenue, following Springville Creek west to Fresh Kills Creek.

77. From 20 foot contour, near Old Turnpike, south along valley of stream, and west along Richmond Creek to Fresh Kills Pumping Station.

78. From Union avenue, southwest, generally parallel to Fresh Kills Creek, to west end of Fresh Kills Force-main.

79. No trunk has been designed for Area 79, but its flow will drain directly into the pump-well of the Lakes Island Pumping Station.

Division I.

80. From near Union avenue, west along valley of Neck Creek to shore, following shore north to junction with Trunk 81 at mouth of small creek, opposite Pralls Island.

81. From 10-foot contour, west along valley of creek to Trunk 80.

80–81. From junction of Trunks 80 and 81, north along shore of Arthur Kill to Bloomfield Purification Works, at a point north of Pralls Island.

82. From 10-foot contour, near Simonson avenue, west along valley of Old Place Creek to junction with Trunk 83.

83. From 10-foot contour, near Decker avenue, north to Trunk 82 at Old Place Creek.

84. From 10-foot contour, near South avenue, west along Bridge Creek to Western avenue, southwest to Old Place road, across Old Place Creek to Junction with Interceptor IX.

85. From near mouth of Old Place Creek, south along shore of Arthur Kill to Bloomfield Purification Works.

Design of Trunk Sewers from Each Area.

The daily flow of sewage has been assumed as equal to the water consumption, and for lack of more definite information, this latter figure has been taken at 125 gallons per capita per day.

Sewers are in all cases designed for maximum sanitary flow, as determined from the assumed future population and per
158 capita water consumption. No allowance has been made for storm flow in this district. Ground water is taken uniformly at 0.003 second feet per acre.

Future population has been assumed as suburban in character, with a density of 25 persons per acre, uniformly distributed over the entire district.

For the peak load upon the system, the maximum flow is assumed to be at a rate which would carry off half the daily flow in eight hours.

Trunks and branches, in which the flow is apt to vary greatly from the assumed maximum, owing to the comparatively small areas served, and liability to local influences, have been designed to carry the assumed maximum flow when only half full, in order to provide for contingencies, while the interceptors, in which the flow will equalize and be much more uniform, have been designed to carry the assumed maximum flow when eight tenths full.

The design for size, grade, etc., has been made from the diagrams in Swan & Horton's "Hydraulic Diagrams," and from a diagram of hydraulic elements for circular sections, in the same book, the discharges and velocities for the sewers 0.8, 0.5, 0.2 and 0.1 full, have been computed.

Except in very few cases, the grades have been taken so as to insure a velocity of 3.0 feet per second or greater, which will give a velocity of 1.8 feet per second when flowing 0.2 full, or at only 0.085 full discharge. This velocity is thought to be sufficient for self-cleansing purposes.

In all siphons, force-mains and outfalls, an effort has been made to secure a uniform velocity of 3.0 feet per second, as nearly as commercial sizes of cast iron pipe will permit.

All designs contemplate circular sections only.

The datum plane for all elevations is the plane of Mean Sea Level at Sandy Hook, as established by the U. S. Coast and Geodetic Survey.

When elevations are given, they refer invariably to the invert of the sewer, unless otherwise specifically stated.

In all cases where the depth of a sewer is mentioned, the depth to the inner top is meant; i. e., the depth to the invert, less the diameter.

In all possible cases, an earth covering of six feet over the inner top of the sewers has been allowed. In no case has this covering been reduced to less than four feet.

Wherever possible, the grades have been taken so as to fit the slope of the ground, but where this would give velocities in excess of about 7.5 feet per second, or where a portion of the ground has a slope flatter than the remainder, a flat grade has been adopted, and the sewer left at a uniform depth of about four to six feet by drop manholes installed at convenient intervals.

At the low-lying portions of the Borough, it is assumed that the

finished grade of the surface, behind the bulkhead wall, will be about 7.35 feet above the datum of Mean Sea Level, or 5.0 feet above Mean High Water (Dock Department).

Whenever possible, at the junction of a trunk with an interceptor the invert of the former is elevated above that of the latter by an amount equal to the difference of diameter, or by half the diameter of the interceptor, if the difference of diameter exceeds this. This is done in order to preserve an unbroken invert in the interceptor, and thus prevent eddies and consequent deposits of suspended solids, and to prevent backing up into small trunks. This
159 elevation is not given where two trunks unite to form an interceptor, nor, obviously, where the two sewers are of the same diameter.

Where an existing storm sewer is intercepted, the interceptor is designed to take only the dry weather flow, and the remaining length of the storm sewer will be maintained and utilized as a storm overflow, to prevent choking of the interceptor.

In the following table are summarized the principal elements involved in the design of these trunk sewers, namely, length, total fall, elevation of invert at upper end, tributary area, slope, maximum diameter, maximum discharge, and velocities and discharges at 0.8 and at 0.2 full.

Design of Trunk Sewers.

Trunk No.	Length, feet.	Total fall, feet.	Elevation of invert, upper end.	Tributary area, acres.	Slope 1, foot in—	Maximum diameter, feet.	Maximum discharge, sec. ft.	Sewer 0.8 full. Velocity, sec. ft.	Sewer 0.8 full. Discharge, sec. ft.	Sewer 0.2 full. Velocity, sec. ft.	Sewer 0.2 full. Discharge, sec. ft.
A—											
1											
Sec. 1......	5,000	10.00	2.40	336	500	1.83	3.44	2.88	6.74	1.50	0.50
Sec. 2......	4,770	9.54	7.04	336	500	1.83	3.44	2.88	6.74	1.50	0.50
2	12,800	32.00	24.40	1,085	400	2.75	11.10	4.37	21.75	2.28	1.80
1-2	3,960	4.40	—7.00	1,421	900	3.50	14.54	3.45	28.50	1.80	2.48
3	6,470	16.18	4.18	339	400	1.83	3.47	3.22	6.80	1.08	0.50
1-3	*.....	....	....	....	...	....	....	....	....	....	....
4	13,850	198.00	229.65	1,235	70	2.17	12.63	8.51	24.77	4.44	2.15
5	5,280	52.80	387.85	555	100	1.67	5.68	6.10	11.11	3.18	0.97
6	4,300	87.40	222.45	311	50	1.25	3.18	6.67	6.24	3.48	0.54
5-6	4,220	21.10	135.05	866	200	1.75	8.86	4.60	8.86	2.40	0.77
7	†.....	....	....	....	...	....	....	....	....	....	....
5-7	3,700	82.30	113.95	1,340	45	1.67	13.70	8.63	13.70	4.50	1.19
8	7,920	79.20	100.62	603	100	1.75	6.17	6.10	12.10	3.18	1.05
9	5,020	125.40	147.23	411	40	1.25	4.30	7.83	8.23	4.08	0.72
B—											
10	7,000	140.00	100.45	277	50	1.17	2.84	6.44	5.57	3.36	0.48
11	†.....	....	....	....	...	....	....	....	....	....	....
12	†.....	....	....	....	...	....	....	....	....	....	....
13 *........	3,300	11.00	96.03	298	300	1.67	3.05	3.45	5.98	1.80	0.52
14	†.....	....	....	....	...	....	....	....	....	....	....
13-14	4,480	42.00	85.03	728	105	1.50	7.45	5.40	7.45	2.82	0.65
15	†.....	....	....	....	...	....	....	....	....	....	....
13-15	2,770	30.80	42.43	1,320	90	1.75	13.50	6.67	13.50	3.48	1.17
16	4,800	85.10	95.06	453	57	1.50	4.63	7.01	9.07	3.66	0.79
17	5,150	49.05	56.53	411	105	1.50	4.30	5.53	8.24	2.88	0.71
C—											
18	11,350	189.20	230.37	736	60	1.67	7.53	7.94	14.75	4.14	1.28
19	5,940	118.80	150.97	644	50	1.67	6.50	8.65	12.91	4.50	1.12
20	3,300	91.60	126.83	215	36	1.00	2.30	6.80	4.31	3.54	0.37

21	7,260	85.40	115.52	408	85	1.50	4.17	5.87	8.17	3.06	0.71
22	8,710	174.00	205.87	615	50	1.50	6.29	8.05	12.32	4.20	1.07
161											
23	†.....	....	....	1,073	150	2.33	10.98	6.10	21.50	3.18	1.87
22-23	5,670	37.80	50.87	201	70	1.17	2.67	5.75	5.23	3.00	0.45
24	4,300	62.30	103.80	265	35	1.17	2.71	7.25	5.30	3.78	0.46
25	2,240	64.00	105.59	157	185	1.17	1.61	3.45	3.16	1.80	0.27
26	2,110	11.40	46.78	365	110	1.50	3.74	5.18	7.33	2.70	0.64
27	7,000	63.70	122.77	....	...	....	....	....	....	....	....
28	†.....	....	....	1,076	180	2.50	11.01	5.75	21.00	3.00	1.87
27-28	5,080	31.55	59.07	312	170	1.50	3.19	4.28	6.25	2.22	0.54
29	5,020	29.56	68.50	341	300	1.75	3.49	3.45	6.84	1.80	0.59
30	2,510	8.37	47.31	653	300	2.17	6.68	4.14	13.10	2.16	1.14
29-30	3,040	10.12	38.94	405	150	1.67	4.14	4.72	8.11	2.46	0.70
31	2,640	17.60	45.15	107	50	0.83	1.00	5.06	2.14	2.64	0.19
32	2,110	42.20	65.61	180	70	1.17	1.84	5.18	3.00	2.70	0.31
33	3,040	43.43	65.63								
D—											
34	7,920	28.80	53.70	250	275	1.50	2.56	3.45	5.02	1.80	0.44
35	1,450	41.45	66.35	294	35	1.17	3.01	7.48	5.90	3.90	0.51
34-35	2,510	5.58	24.90	544	450	2.17	5.57	3.45	10.91	1.80	0.95
36	9,640	192.50	220.27	482	50	1.50	4.94	7.48	9.08	3.90	0.84
37	5,940	59.40	87.17	307	100	1.50	3.14	5.75	6.15	3.00	0.53
36-37	990	11.00	27.77	789	60	1.75	8.08	8.05	15.83	4.20	1.37
38	2,380	36.62	51.33	98	65	0.83	1.00	4.49	1.96	2.34	0.17
39	2,640	37.73	50.97	71	70	0.75	0.73	4.62	1.43	2.10	0.12
40	8,580	25.24	16.73	642	340	2.17	6.57	4.63	12.89	2.10	1.12
41	5,280	12.42	3.91	499	425	2.17	5.10	3.45	10.00	1.80	0.87
40-41	1,190	1.49	—8.51	1,141	800	3.17	11.67	3.45	22.85	1.80	1.98
42	6,000	11.00	1.00	681	600	2.50	6.97	3.45	13.67	1.80	1.19
40-42	*.....	....	....	....	...	....	....	....	....	....	....
43	5,940	109.70	182.00	398	35	1.25	4.07	8.05	7.96	4.20	0.69
44	2,640	75.50	86.41	301	35	1.17	3.08	7.47	6.05	3.90	0.52
45	3,830	76.60	85.75	238	50	1.17	2.43	6.20	4.76	3.24	0.41
46	1,980	79.30	87.57	133	25	0.83	1.36	6.90	2.66	3.60	0.23

*Force main. †No trunk designed.

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Trunk No.	Length, feet.	Total fall, feet.	Elevation of invert, upper end.	Tributary area, acres.	Slope 1, foot in—	Maximum diameter, feet.	Maximum discharge, sec., ft.	Sewer 0.8 full. Velocity, sec., ft.	Sewer 0.8 full. Discharge, sec., ft.	Sewer 0.2 full. Velocity, sec., ft.	Sewer 0.2 full. Discharge, sec., ft.
E—											
47	6,600	22.00	23.87	279	300	1.67	2.86	3.45	5.61	1.80	0.49
48	2,640	8.80	10.67	302	300	1.67	3.09	3.45	6.06	1.80	0.53
47-48	2,770	9.23	1.87	581	300	1.67	5.95	3.45	5.95	1.80	0.52
49	6,070	8.68	1.32	511	700	2.33	5.23	2.88	10.25	1.50	0.89
47-49	1,320	2.64	—7.36	1,092	500	2.25	11.18	3.45	11.18	1.80	0.97
50	8,580	14.30	4.30	739	600	2.67	7.56	3.45	14.81	1.80	1.29
51	5,940	14.86	4.86	161	400	1.50	1.65	2.53	3.24	1.32	0.28
F—											
52	8,840	47.75	55.89	440	185	1.75	4.50	4.60	8.82	2.40	0.77
53	5,540	50.40	58.54	342	110	1.50	3.50	5.18	6.86	2.70	0.59
54	7,390	54.75	57.32	498	135	1.67	5.09	5.30	9.98	2.76	0.87
55	9,640	48.20	40.92	695	200	2.17	7.11	4.84	13.94	2.52	1.21
56	7,660	95.90	107.75	545	80	1.67	5.58	6.55	10.93	3.42	0.95
57	5,020	77.25	89.10	265	65	1.17	2.71	5.75	5.30	3.00	0.46
56-57	3,430	17.15	11.85	810	200	2.17	8.29	5.18	16.24	2.70	1.41
58	†.....	.....	.....	...	...	....	....	....	....	....	....
56-58	4,220	4.70	—5.30	1,362	900	3.50	13.94	3.45	27.30	1.80	2.37
G—											
59	10,560	19.20	7.20	713	550	2.50	7.29	3.45	14.29	1.80	1.24
60	7,130	57.00	45.00	471	125	1.67	4.82	5.30	9.45	2.76	0.82
61	2,640	88.00	90.02	198	30	1.00	2.03	7.02	3.98	3.66	0.36
62	3,830	47.90	39.54	322	80	1.33	3.29	5.75	6.45	3.00	0.56
63	8,580	90.40	81.87	436	95	1.50	4.46	5.75	8.74	3.00	0.76
64	7,260	14.52	4.52	291	500	1.75	2.98	2.88	5.84	1.50	0.51
65	3,300	60.00	50.00	193	55	1.17	1.97	5.75	3.86	3.00	0.34
66	6,860	22.90	12.90	388	300	1.83	3.97	3.68	7.78	1.92	0.68
67	7,390	18.45	13.95	339	400	1.83	3.47	3.22	6.80	1.68	0.59
68	4,220	52.80	48.30	470	80	1.50	4.81	6.22	9.44	3.24	0.82
67-68	3,300	5.50	—4.50	809	600	2.67	8.28	3.45	16.22	1.80	1.41

H—											
69	6,070	12.13	2.13	340	500	2.00	3.48	2.88	6.82	1.50	0.59
70	3,830	11.95	1.95	318	320	1.67	3.25	3.45	6.37	1.80	0.55
71	1,580	13.73	17.09	87	115	1.00	0.89	3.45	1.74	1.80	0.15
72	6,730	13.45	10.95	324	500	1.83	3.31	2.88	6.48	1.50	0.56
73	1,980	9.90	7.40	186	200	1.33	1.90	3.45	3.72	1.80	0.32
72-73	1,450	3.22	—2.50	510	450	2.17	5.21	3.45	10.20	1.80	0.89
74	8,450	14.08	4.75	755	600	2.67	7.72	3.45	15.13	1.80	1.31
75	11,880	13.20	9.36	654	900	2.67	6.69	2.88	13.11	1.50	1.14
76	6,340	7.04	3.20	695	900	2.75	7.11	2.88	13.93	1.50	1.20
77	8,710	17.42	7.42	568	500	2.25	5.81	3.45	11.38	1.80	0.99
163											
78	7,520	7.52	0.48	915	1,000	3.17	9.36	2.88	18.36	1.50	1.59
79	†.....	....	....	...	...	....	....	....	....	....	....
I—											
80	8,700	14.50	5.47	408	600	2.17	4.17	2.88	8.17	1.50	0.71
81	5,680	11.34	2.31	630	500	2.33	6.44	3.45	12.61	1.80	1.09
80-81	3,560	2.97	—9.03	1,038	1,200	3.33	10.61	2.88	20.80	1.50	1.80
82	8,180	13.63	8.82	817	600	2.67	8.36	3.45	16.38	1.80	1.42
83	3,040	6.08	1.27	606	500	2.33	6.20	3.45	12.15	1.80	1.05
84	7,260	11.19	3.45	845	650	2.75	8.64	3.45	16.92	1.80	1.47
85	5,680	10.81	—1.19	618	525	2.33	6.32	3.45	12.38	1.80	1.07

† No trunk designed.

164 Design of Intercepting Sewers.

The design of these sewers is determined by the available slope and by the points of entrance of the various trunk sewers. Sizes are based upon normal flow with sewers .8 full. To facilitate reference, the nine interceptors have each been subdivided into sections designated by letters and beginning at the upper end in each case. These sections are described as follows:

Divisions A and B.

Interceptor I.

a. From Columbia street along Post avenue, Elizabeth street, Castleton avenue, Broadway, two intervening streets and Henderson avenue to junction with Trunk 8 at Rement avenue.

b. From Rement avenue, east along Henderson avenue, along 30-foot contour and Richmond terrace to junction with Trunk 9 at Lafayette avenue.

c. From Lafayette avenue, along Richmond terrace to junction with Trunk 10 at Jersey street.

d. From Trunk 10 at Jersey street, along Richmond terrace to Church street.

e. From Church street, along Richmond terrace, Jay street, South street, Stuyvesant place, Central avenue to Arietta street.

f. From Central avenue, along Arietta street, Van Duser, Hanna street, St. Paul's avenue, Clinton, Van Duser, Wright and Boyd streets, across to junction with Trunk 13-14-15 at Canal street.

g. From Canal street, along Riker and Tompkins streets, and various other streets at about the 30-foot contour to Trunk 16 at Willow avenue.

h. From Willow avenue, south to Maple avenue; thence along Maple and New York avenues to junction with Trunk 17 at Pennsylvania avenue.

i. From junction with Trunk 17, east along Pennsylvania avenue to shore.

j. Outfall Section—From foot of Pennsylvania avenue, east to water 50 feet deep in channel.

Divisions C and D.

Interceptor II.

a. From Rockland avenue, following 50-foot contour south to junction with Trunk 20, south of Richmond Hill road.

b. Following 50-foot contour south from Trunk 20 to junction with Trunk 21, near Old Mill road.

c. From Trunk 21, following 40-foot contour eastward around spur of ridge to junction with Trunk 22-23 at Richmond Creek.

d. Richmond Creek Siphon—From junction with Trunk 22-23, east under Richmond Creek to Interceptors III. and IV.

Interceptor III.

a. From Trunk 25, following approximately the 50-foot contour to junction with Trunk 26 at Greenridge avenue.

b. From Greenridge avenue, following 50-foot contour east to junction with Trunk 27-28, near small creek.

c. Eltingville Road Siphon—From junction with Trunk 27-28, east under stream to Trunk 29-30.

165 *d.* From Trunk 29-30, following the 40-foot contour northeast to junction with Trunk 31, near fork of stream.

e. From Trunk 31, following 40-foot contour north to junction with Trunk 32, south of Clark avenue.

f. From Trunk 32, north to east end of Richmond Creek Siphon.

Interceptor IV.

a. From east end of Richmond Creek Siphon, east to junction with Trunk 33, north of Clark avenue.

b. From Trunk 33, north and east to junction with Trunk 34-35 on Amboy road.

c. From Trunk 34-35, at Amboy road, east to Tenth street, New Dorp, following Tenth street to junction with Trunk 36-37 at prolongation of Elm avenue.

d. From Trunk 36-37, north along 30-foot contour, Lincoln avenue and Thompson street to junction with Trunk 38 at Barton avenue.

e. From Trunk 38, at Barton avenue, following 30-foot contour to junction with Trunk 39 at Liberty avenue, Dongan Hills.

f. From Trunk 39, at Liberty avenue, north along 30-foot contour to junction with Sea View Avenue Force-Main.

g. From Sea View Avenue Force-Main, north along 30-foot contour to Trunk 43, south of Burgner avenue.

h. From Trunk 43, north and east along 30-foot contour to Trunk 44 on Parkinson avenue.

i. Along 20-foot contour, from Trunk 44 at Parkinson avenue to Trunk 45 at Sand Lane road.

j. From Trunk 45, on Sand Lane road, east along 20-foot contour and Old Town avenue to junction with Trunk 46 on Sea avenue.

k. From Old Town avenue, south along prolongation of Sea avenue to shore.

l. Outfall Section—From foot of Sea avenue, prolonged to shore, east 3,500 feet to water 50 feet deep in channel.

Division E. Division F.

Interceptor V.

a. From junction of Trunks 52 and 53, at Barclay avenue, following shore south and west to junction with Trunk 54, at Latourette's Pond.

b. From Latourette's Pond, following shore southwest to junction with Trunk 55, near Wolf's Pond.

c. From Wolf's Pond, southwest along shore to Seguine's Point Pumping Station.

d. From Seguine's Point Pumping Station, southeast to water 21 feet deep, 800 feet off shore.

Division G.

Interceptor VI.

a. Kreischerville Force Main—From Kreischerville Relay Pumping Station, at south end of Trunk 59, south, parallel to shore of Arthur Kill to junction with Trunk 61, at Kreischer street, Kreischerville.

b. From south end of Kreischerville Force-Main, south along shore of Arthur Kill and east along Mill Creek to junction with Trunks 62 and 63, near Richmond Valley road.

166 *c.* Mill Creek Siphon—From Junction of Trunks 62 and 63, south under Mill Creek to Mill Creek Pumping Station, on south bank of creek.

d. Mill Creek Force-Main—From Mill Creek Pumping Station, southeast to summit of ridge.

e. From Mill Creek Force-Main, at summit of ridge, southeast to Red Bank Pumping Station, at shore.

f. Gravity Outfall Section—From Red Bank Pumping Station, southeast to 21 feet of water, 1,600 feet off shore.

Division H.

Interceptor VII.

a. Richmond Creek Force-Main—From Richmond Creek Pumping Station, near Fresh Kills Bridge, west under Mill Pond outlet to junction with Trunk 71, near bend in Richmond Creek.

b. From junction with Trunk 71, at west end of Richmond Creek Force-Main, west along Richmond Creek to junction with Trunk 72-73, near fork of Fresh Kills.

c. From junction with Trunk 72-73, west to junction with Trunk 74, at a point on Fresh Kills opposite Lake's Island.

d. Fresh Kills Siphon—From junction with Trunk 74, on east bank, west under Fresh Kills to Lake's Island.

e. From west end of Fresh Kills Siphon, west to Lake's Island Purification Works, on the shore of Arthur Kill.

Interceptor VIII.

a. From junction of Trunks 75 and 76, at Springville Creek, south to Fresh Kills Pumping Station.

b. Fresh Kills Force-Main—From Fresh Kills Pumping Station, northwest under Fresh Kills Creek to Trunk 78, north of Little Fresh Kills.

c. From west end of Fresh Kills Force-Main at junction with Trunk 78, southwest to north bank of Little Fresh Kills.

d. Little Fresh Kills Siphon—From north bank, southwest under Little Fresh Kills to Lake's Island.

e. From south end of Little Fresh Kills Siphon, southwest to Lake's Island Purification Works, on shore of Arthur Kill.

f. Outfall Section from Purification Works—From Lake's Island Purification Works west to 21 feet of water in Arthur Kill, 800 feet off shore.

Division I.

Interceptor IX.

a. From junction of Trunks 82 and 83, west along Old Place Creek to junction with Trunk 84, near Old Place road.

b. From junction with Trunk 84, southwest to Bloomfield Purification Works, on shore of Arthur Kill, north of Prall's Island.

c. Outfall Section from Bloomfield Purification Works—From Bloomfield Purification Works west to 21 feet of water in Arthur Kill, 750 feet off shore.

The total length, total fall, in each section, elevation of invert at upper end, tributary area, slopes, maximum diameter, maximum discharge and discharges at .8 and .2 full for each section of these nine interceptors are summarized below:

167

Design of Interceptors.

Section.	Length, feet.	Total fall, feet.	Elevation of invert, upper end.	Tributary area, acres.	Slope 1, foot in—	Maximum diameter, feet.	Maximum discharge, feet.	Sewer 0.8 full. Velocity, sec. ft.	Sewer 0.8 full. Discharge, sec. ft.	Sewer 0.2 full Velocity, sec. ft.	Sewer 0.2 full Discharge, sec. ft.
A-B— I.											
a	5,280	4.40	29.49	4,335	1,200	4.33	44.34	3.45	44.34	1.80	3.84
b	7,390	5.68	25.09	4,938	1,300	4.67	50.51	3.45	50.51	1.80	4.39
c	2,110	1.46	19.41	5,349	1,450	4.83	54.71	3.45	54.71	1.80	4.75
d	1,450	0.97	17.95	5,626	1,500	5.00	57.55	3.45	57.55	1.80	5.00
e	5,670	3.78	16.98	5,734	1,500	5.17	58.65	3.45	58.65	1.80	5.09
f	6,600	4.40	13.20	5,829	1,500	5.17	59.62	3.45	59.62	1.80	5.18
g	4,490	2.56	8.80	7,149	1,750	5.67	73.12	3.45	73.12	1.80	6.35
h	3,170	1.76	6.24	7,602	1,800	5.83	77.75	3.45	77.75	1.80	6.74
i	920	0.48	4.48	8,013	1,900	6.00	81.95	3.45	81.95	1.80	7.12
j	Outfall section.										
C-D— II.											
a	4,360	7.27	41.17	1,380	600	2.50	14.12	3.45	14.12	1.80	1.23
b	3,300	5.28	33.90	1,595	625	2.67	16.32	3.45	16.32	1.80	1.42
c	5,410	7.22	28.62	2,003	750	3.00	20.49	3.45	20.49	1.80	1.78
d	Richmond Creek siphon										
III.											
a	3,160	7.04	41.59	526	450	1.67	5.38	2.88	5.38	1.50	0.47
b	4,220	7.03	34.55	683	600	2.00	6.99	2.88	6.99	1.50	0.61
c	Eltingville road siphon.										
d	2,380	1.77	27.32	2,412	1,350	3.67	24.68	2.88	24.68	1.50	2.14
e	6,200	4.14	25.55	2,817	1,500	4.00	28.82	2.88	28.82	1.50	2.50
f	1,060	0.71	21.41	2,924	1,500	4.00	29.91	2.99	29.91	1.56	2.60
168											
C-D— IV.											
a	1,720	1.15	20.70	6,000	1,500	5.17	61.38	3.45	61.38	1.80	5.32
b	4,620	2.98	19.55	6,180	1,550	5.25	63.22	3.45	63.22	1.80	5.49

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	c	4,620	2.72	16.57	6,724	1,700	5.50	68.79	3.45	68.79	1.80	5.97
	d	3,700	2.06	13.85	7,513	1,800	5.83	76.87	3.45	76.87	1.80	6.65
	e	2,900	1.57	11.79	7,811	1,850	5.83	77.87	3.45	77.87	1.80	6.73
	f	200	0.14	10.22	7,982	1,850	6.00	78.69	3.45	78.69	1.80	6.82
	g	1,060	0.51	10.08	9,504	2,100	6.50	97.24	3.45	97.24	1.80	8.45
	h	4,480	2.04	9.57	9,602	2,200	6.67	101.31	3.45	101.31	1.80	8.80
	i	3,960	1.80	7.53	10,203	2,200	6.75	104.39	3.45	104.39	1.80	9.65
	j	2,110	0.88	5.73	10,441	2,400	6.83	106.82	3.45	106.82	1.80	9.25
	k	700	0.35	4.85	10,574	2,400	6.83	108.18	3.45	108.18	1.80	9.30
E—												
F—												
V.												
	a	2,240	6.40	8.14	782	350	2.00	8.00	3.45	8.00	1.80	0.69
	b	5,410	9.85	1.74	1,280	550	2.50	13.09	3.45	13.09	1.80	1.13
	c	1,320	1.89	—8.11	1,975	700	3.00	20.20	3.45	20.20	1.80	1.75
	d	Outfall section.										
G—												
VI.												
	a	Kreischerville force main.										
	b	6,200	10.30	0.77	1,382	600	2.50	14.14	3.45	14.14	1.80	1.22
	c	Mill Creek siphon.										
	d	Mill Creek force main.										
	e	3,700	24.68	28.68	2,624	150	2.50	26.84	6.68	26.84	3.48	2.34
	f	Outfall section.										
H—												
VII.												
	a	Richmond Creek force main.										
	b	5,150	8.58	2.36	745	600	2.00	7.62	2.88	7.62	1.50	0.66
169												
	c	2,640	3.11	—6.22	1,255	850	2.67	12.83	2.88	12.83	1.50	1.11
	d	Fresh Kills siphon.										
	e	1,580	2.26	—9.74	2,010	700	3.00	20.55	3.45	20.55	1.80	1.78

Section.	Length, feet,	Total fall, feet.	Elevation of invert, upper end.	Tributary area, acres.	Slope 1, foot in—	Maximum diameter, feet.	Maximum discharge, feet.	Sewer 0.8 full. Velocity, sec. ft.	Sewer 0.8 full. Discharge, sec. ft.	Sewer 0.2 full. Velocity, sec. ft.	Sewer 0.2 full. Discharge, sec. ft.
VIII.											
a	5,540	6.16	—3.84	1,349	900	2.75	13.80	2.88	13.80	1.50	1.20
b	Little Fresh Kills force main.										
c	1,980	2.20	—7.37	2,832	900	3.50	28.97	3.45	28.97	1.80	2.51
d	Little Fresh Kills siphon.										
e	1,720	1.91	—10.09	2,832	900	3.50	28.97	3.45	28.97	1.80	2.51
f	Outfall section.										
1— IX.											
a	2,640	2.93	—4.81	1,423	900	2.75	14.56	2.88	14.56	1.50	1.26
b	5,540	4.26	—4.74	2,268	1,300	3.50	23.20	2.88	23.20	1.50	2.01
c	Outfall section.										

170 Pumping Stations and Force Mains.

These plans contemplate the establishment of eleven pumping stations, the ultimate maximum capacity and the approximate locations of which are tabulated below. The capacities given are net horse-power without reference to efficiency and refer to total lift between pump well level and elevation of upper flow-line or ordinary maximum high tide as the case may be and include estimated loss of head in force-mains.

Table of Pumping Stations.

Designation.	Serving.	Discharge, sec. ft.	Lift, feet.	Power developed, h. p.
Van Pelt avenue relay	Trunk No. 1	3.44	5.82	2.40
Sea View avenue	Sea View avenue force main	18.64	27.56	58.30
Great Kills	Outfall E	20.30	16.17	37.40
Seguine's Point	Outfall F	34.14	13.54	52.50
Red Bank	Outfall G low level lift	12.25	14.13	22.30
Mill Creek	Mill Creek force main	26.84	42.16	128.90
Kreischerville	Kreischerville force main	12.11	16.48	22.65
Lake's Island	Lakes Island purification works	50.75	16.61	95.90
Richmond Creek	Richmond Creek force main	6.73	17.70	13.53
Fresh kills	Fresh Kills force main	19.61	6.79	15.13
Bloomfield	Bloomfield purification works	40.13	16.66	76.00
Total power required				525.01

There will be six force-mains in the ultimate development of this plan, the essential details of which are tabulated below:

Table of Force-Mains.

Designation.	Length, feet.	Max. disch., sec. ft.	Vel., ft. per sec.	Diam., feet.	Elev. pump well.	*Lift, feet.	Power required, h. p.
Columbia St., Trunk 1-2-3	2,240	18.01	2.55	3.0	—12.00	45.87	93.85
Sea View Ave., Trunk 40-41-42	5,280	18.64	2.64	3.0	—10.00	27.56	58.30
Kreischerville, Intercept. VI. *a*	2,640	12.11	2.84	2.33	—12.00	16.48	22.65
Mill Creek, Intercept. VI. *d*	3,500	26.84	2.79	3.5	—10.00	42.16	128.90
Richmond Creek, Intercept. VII. *a*	2,100	6.73	3.09	1.67	—10.00	17.70	13.53
Fresh Kills, Intercept. VIII. *b*	3,040	19.61	2.77	3.0	—10.00	6.79	15.13

* NOTE.—The lift as given includes the loss of head in the pipe.

171 Siphons.

Five inverted siphons will be required located as follows:

Richmond Creek Siphon (Interceptor II., section *d*)—From junction Trunk 22-23, east under Richmond Creek to Interceptors III. and IV.

Eltingville Road Siphon (Interceptor III., section *c*)—From junction with Trunk 27-28, east under stream to Trunk 29-30.

Mill Creek Siphon (Interceptor VI., section *c*)—From Junction of Trunks 62 and 63, south under Mill Creek, to Mill Creek Pumping Station, on south bank of creek.

Fresh Kills Siphon (Interceptor VII., section *d*)—From junction with Trunk 74, on east bank, west under Fresh Kills to Lake's Island.

Little Fresh Kills Siphon (Interceptor VIII., section *d*)—From north bank, southwest under Little Kills to Lake's Island.

The essential details of these siphons are tabulated below:

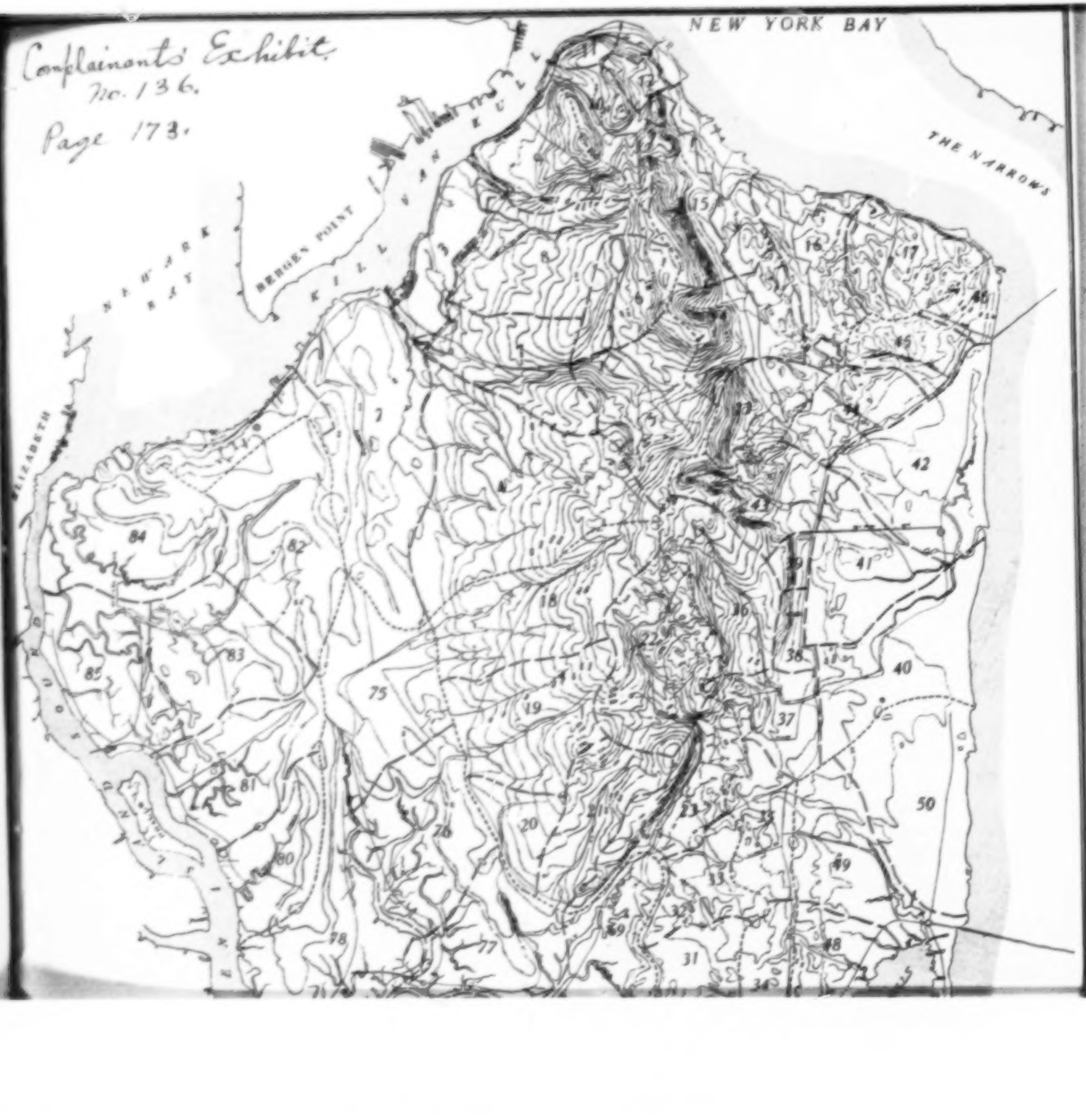
Table of Siphons.

Designation.	Location.	Length, feet.	Diameter, feet.	Maximum discharge.	Velocity, feet per second.	Loss of head, feet.
Richmond Creek Interceptor II. (*d*).	Under Richmond Creek.	920	3.5	31.47	3.27	0.79
Eltingville road Interceptor III. (*c*).	Near Eltingville road..	200	3.0	18.00	2.55	0.29
Mill Creek Interceptor VI. (*c*)..	Under Mill Creek......	530	3.0	21.90	3.10	0.47
Fresh Kills Interceptor VII. (*d*)..	Under Fresh Kills.....	530	3.0	20.55	2.90	0.41
Little Fresh Kills Interceptor VIII (*d*)	Under Little Fresh Kills................	700	3.5	27.97	3.01	0.32

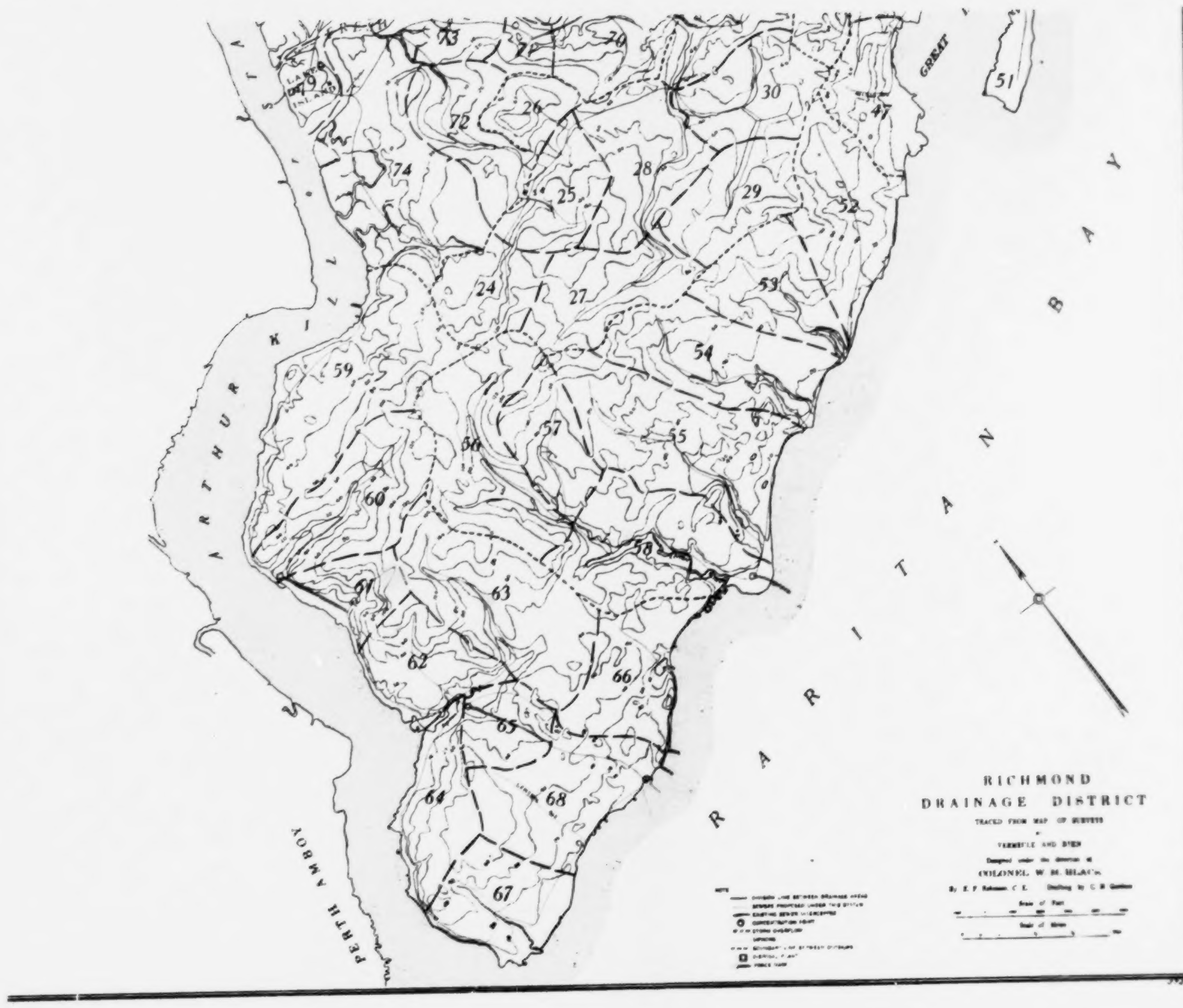
Points of Discharge, Pollution of Waters, and Purification Necessary.

The seven outfall sewers have been described as the last section in each case of the seven interceptors. Their location is more definitely shown upon the accompanying map. The question of the effect of these discharges upon the surrounding waters and of the purification necessary for the prevention of nuisance, is discussed fully in our general report upon the pollution of the waters of New York Harbor and the purification of sewage entering these waters. For the reasons more fully discussed in that report, no purification is thought necessary for Outfalls A-B, C-D, E-F and G. Outfalls H and I both discharge into the Arthur Kill. Owing to the comparatively poor tidal circulation available at these points, the small volume of water in which the discharge takes place, and the relatively large amount of pollution at present existing in these waters, it is recommended that a partial purification of the sewage from both of these outfalls be undertaken. A process of short-time sedimentation and of forced aeration similar to that employed by us in our Brooklyn experiments will probably be found satisfactory and sufficient.

The further details of the design of these outfall sewers which was omitted from the table of interceptors is summarized below:



Complainants' Exhibit
No. 136.
Page 173.
NEW YORK BAY
THE NARROWS
KILL VAN KULL
BERGEN POINT
NEWARK BAY
ELIZABETH


RICHMOND
DRAINAGE DISTRICT
TRACED FROM MAP OF SURVEYS
GREAT
BAY
RARITAN
ARTHUR KILL
PERTH AMBOY
51
30
47
73
71
70
79
26
72
74
28
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25
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Table of Outfalls.

Number.	Maximum discharge, sec. ft.	Discharge, gallons. per 24 hours.	Discharge by	Diameter, feet.	Length, feet.	Distance off shore, feet.	Depth discharge, feet.
A-B	81.95	40,594.824	Gravity	2-4	600	600	50
C-D	108.18	53.586.000	Gravity	3-4	3.500	3.500	50
E	20.39	10,099,300	Force main	3.0	6,200	5,000	12
F	34.14	16,910,856	Force main	4.0	1,580	800	21
G	39.09	19,362,888	Gravity	4.0	1.720	1,600	21
H	50.75	25,139,376	Gravity	4.5	1,060	800	21
I	40.13	19,878.912	Gravity	4.0	1,060	750	21

Very respectfully,

W. M. BLACK.
EARLE B. PHELPS.

New York, February 15, 1911.

(Here follows map marked page 173, Complainants' Exhibit 136.)

174 *Special Report on the Oxygen Content of Sea Water as a Standard for Measuring Sewage Pollution Submitted to the Board of Estimate and Apportionment July 1, 1910.*

175 BOARD OF ESTIMATE AND APPORTIONMENT,
CITY OF NEW YORK, June 27, 1910.

Hon. William J. Gaynor, Mayor, Chairman of the Board of Estimate and Apportionment.

SIR: Colonel William M. Black, who is making an investigation of the location of sewer outlets and of the disposal of sewage for the Board of Estimate and Apportionment, and Professor Phelps, who is associated with him in this work, have handed me a report dated June 7, in which they point out the important bearing which the amount of unpolluted water daily entering the harbor of New York has upon the sewerage problem, and the lack of definite information upon this subject.

There is no question but that the starting point of any investigation designed to offer a solution of this problem must be a determination of the capacity of the harbor to take care of the sewage discharged into it without permitting the water to become so polluted as to be offensive. While some data has been collected by the United States Coast and Geodetic Survey and by the New York Bay Pollution Commission, the information is very meagre. The report of the Metropolitan Sewerage Commission has not been published, but I understand that this Commission has not secured sufficient information along these lines to lead to a definite conclusion. This would seem to be an excellent line of investigation for this Commission to follow, and I would recommend that the report of Colonel Black and Professor Phelps be sent to the Metropolitan Sewerage Commission, with the request that the Commission follow the lines of investigation suggested in the report and furnish the Board with such information as it can secure.

Respectfully, NELSON P. LEWIS,
Chief Engineer.

176 NEW YORK CITY, June 7, 1910.

Mr. Nelson P. Lewis, Chief Engineer, Board of Estimate and Apportionment, No. 277 Broadway, New York, N. Y.

DEAR SIR: The question of the proper disposal of the sewage of New York embraces many problems interesting from an engineering and an economic standpoint. For the present and probably for many years to come water carriage is and will be the most economical method of conveying sewage from the points of production to common points of disposal. To-day, the sewage is discharged at many points into the waters bordering the city. These waters form the harbor of New York and are the source of its greatness and even of its life. Their preservation in a condition fit for commerce is essential and no expenditures necessary to that end can be considered too great. The practical business sense of the American citizen only requires that he be convinced of the necessity for a given work in order to induce him to provide the means for its execution.

To-day the condition of purity of these waters is a subject of controversy. Some eminent engineers declare that their capacity for receiving and disposing of sewage is so great as to suffice not only for the needs of the population now found in the drainage area, but also for the probable increase of that population during many years. Others, professing equal technical knowledge, claim that the waters are now overtaxed and that an inadmissible and dangerous degree of pollution already exists. The former cite in support of their opinions analyses of water taken from portions of the harbor which show practically a normal degree of purity. The latter show analyses of specimens taken from other parts which show septic conditions. Both are honest in their professions, but with the system now in use by which sewage is discharged without an attempt at general distribution and without regard to the volume of flow or the circulation of the water in the vicinity of the outlets, it is natural that different localities should show to-day entirely different conditions, and that it is only necessary to make a judicious choice of locality in order to obtain an apparently irrefutable argument in support of either side of the controversy.

In so far as known, no attempt has been made as yet to consider the subject as a whole and to determine whether the capacity of the entire body of water is adequate to the task of receiving and purifying continously the sewage of the drainage area tributary to these waters.

It is evident that if the capacity be adequate, the problem resolves itself into a question of proper distribution, so that no part of this natural purification machine shall be overloaded. If it be insufficient for the work, then the load must be reduced by purifying all of the sewage partially, or by purifying a portion to a higher degree. It is quite conceivable that with improper distribution a part of the machine of limited capacity, such as Gowanus Basin, Newtown Creek or the Harlem River might be overloaded and break down, as evidenced by septic conditions, while another part does little or no work. It is further evident that with proper distribution, purification of a part to the necessary degree can be limited to and carried on at points where the physical conditions are such
177 as to permit the work to be done with the greatest economy,
thus making it possible for the sewage from other localities, under conditions less advantageous for this class of work, to be discharged safely without treatment.

It is economically unwise not to take the fullest advantage consistent with safety of the great purification machine provided by nature. To do this to the best advantage, the question should be trated from the standpoint of the interests and requirements of the population of the entire drainage area, irrespective of the artificial political boundary lines. If legal conditions make this impossible for the present, then minimum subdivision should be made by the corporate limits.

In other words, if the supply of oxygen provided daily to the waters of New York Harbor is sufficient to reduce a portion of the dose of sewage daily discharged into them without causing an undue reduction of their contained oxygen (and the consequent produc-

tion of conditions of pollution), it is evident that artificial purification is required only for the remainder of the sewage, and that the purification of this excess volume can then be carried on to the extent required at those points of discharge where that work can be done most economically and advantageously to the entire community. It would then follow that, in certain districts of the city, sewage could be discharged with proper distribution into the waters without treatment, because of the treatment given elsewhere to other portions of the total daily discharge, and that the cost of the treatment wherever made should be borne by all citizens benefited, that is, by the inhabitants of all districts discharging sewage into the harbor waters. When this general treatment is made, it should not be a borough, or a ward, or a district question. Only by broad general treatment can the best and most economical results be obtained.

The ultimate disposal of sewage, the resolution into its primary elements, like that of all organic waste products, is reached by oxidation. This is true, whether the resolution take place in the air, under the earth or in the water. Water in its normal condition contains in solution a certain quantity of oxygen. About 30 per cent. of this dissolved oxygen can be removed without practical detriment to the limpidity of the water, or to its ability to support major fish life. When an unstable organic substance is discharged into water, oxidation begins at once and continues until the resolution of the substance into its elements has been made. During this process the water parts with its dissolved oxygen. If the circulation of the water be sufficient to divide the loss through a sufficient volume, no harm results, and the water gradually regains its normal oxygen contents from the atmosphere. Should the loss of oxygen be greater than 50 per cent., the water becomes offensive and major fish life disappears. Septic conditions are reached when the oxygen has been exhausted. In these conditions none but the lowest forms of life are possible and offensive gases are evolved.

As stated, the normal supply of dissolved oxygen is restored to exhausted water from the atmosphere. This process is slow in quiet waters. In streams, especially when the flow is swift, and where natural or artificial waterfalls exist, it is more rapid. For example, in 1900, the late Prof. Palmer found that the water of the Chicago Drainage Canal, above the Bear Trap Dam, at Lockport, Ill.,
178 contained 5.9 per cent. of dissolved oxygen, while 200 yards below the dam the aeration produced at the dam had increased the proportion of dissolved oxygen to 70 per cent. of saturation (Lederer, Treatment of Sewage).

In New York Harbor other sources than the reaeration from the atmosphere supply the greater part of the oxygen needed for the daily work of purification.

The sources of supply are as follows:

(*a*) The volume of normal sea water brought into the harbor daily by tidal action.

(*b*) The volume of fresh water discharged from streams emptying into the harbor.

(c) Rainfall reaching the harbor directly or from immediate surface drainage.

(d) A portion of the city water supplies.

(e) Reaeration by surface absorption of oxygen.

The data available from which to obtain a measure of the supply of normal sea water brought in by the tides are found in the publications of the United States Coast and Geodetic Survey relating to the circulation of the sea in New York Harbor. The investigations of the New York Bay Pollution Commission confirm and illustrate the conclusions reached by the United States Coast Survey measurements.

Gaugings of the flow through the Sandy Hook entrance, the Narrows and the North and East Rivers were made in 1886 and earlier years. From several sets of careful measurements made opposite 23d street, East River, Prof. Mitchell found that there was a preponderance of flow westward (south through the East River of about 440,000,000 cubic feet per tide. The conclusion has since been questioned, but inasmuch as the doubt was raised as a result of a theoretical discussion, without further measurement, and since other direct measurements seem to show the preponderance of flow westward, the writers accept Prof. Mitchell's conclusions. At Sandy Hook the preponderant volume of flow is to the south (outward).

To determine an approximate solution of the problem of the amount of oxygen available daily in the East River, the following method is being followed by the writers:

The calculations of the United States Coast and Geodetic Survey show for an average tide the easterly flow through the East River, opposite Old Ferry Point. When this flow begins the water level is at 4.26 feet above the mean low water plane and falling. The mean velocity is given for each lunar hour. While the easterly flow continues, the tide falls from 4.26 feet above mean low water to mean low water, and then rises to 4.47 feet above mean low water. The probable effects to the east of Old Ferry Point are that at the end of the easterly flow the entire body of water in the channel east to Stepping Stone Light, plus the tidal prism of the bays at the side, to the elevation 4.47, is composed of water, more or less polluted, which had flowed out past Old Ferry Point.

When the westerly current sets in, the tide is rising, the flow is through the channel and into the bays. As the tide rises, the tidal prism of the bays is completed from the channel and the volume of water flowing back past Old Ferry Point consists of the water
179 which had flowed out, admixed with a volume of normal
sound water equal to the amount used in filling the tidal prisms of the side bays, plus the preponderance of westward over eastward flows in the East and Harlem Rivers. The volume of this normal sound water thus entering (about 1,000,000,000 cubic feet) gives the measure of the new supply of oxygen provided by one tide, and of this supply 30 per cent. can be used with safety in sewage purification. Before the tide turns again this water has been divided between the East and Harlem Rivers and has entered into its work in the harbor.

For the Sandy Hook entrance the problem is more complex. Since the preponderance of flow is southerly (outward), and since at any one flood tide the fresh sea water is carried but a limited distance into the upper bay, it would seem that, excepting in the lower bay, but a very limited admixture took place. Due, however, to a marked underrun of the northerly flow under the ebb current at the beginning of the flood and for some time before the change in current direction has occurred at the surface, the normal sea water is carried into and distributed through the upper bay and lower Hudson.

For the determination of the volumes of flow the only data available is that supplied by the United States Coast and Geodetic Survey and that obtained from the Engineer Department of the Army. In 1886 and prior years, the Coast Survey made a number of careful measurements of the flow at various sections in the Sandy Hook channels, in the Narrows, the Hudson and the East Rivers. The results were calculated and reported on by the late Prof. Henry Mitchell, whose wide experience made him a most competent investigator. The investigations were confessedly incomplete, for the problem is very complicated and difficult. A lack of funds has prevented their continuation. Other calculations based on the observations then made and on a theoretical discussion have since been made by Dr. Harris of the Coast and Geodetic Survey. Dr. Harris' conclusions as to the relative volumes of flow north and south through the East River differ from those of Prof. Mitchell, in that Dr. Harris believes that the preponderance of southerly flow is much less than that found by Prof. Mitchell. Dr. Harris' discussion assumes that the velocities of the tidal currents follow strictly the laws of variation through a section as do river current velocities. This assumption is not believed to be fully supported by the scanty records of observations available—and the writers believe that Prof. Mitchell's conclusions are probably more nearly correct. The records of surface velocities published in the Atlantic Coast tide tables, as well as the float observations made by the New York Bay Pollution Commission, in so far as reported, would seem to support this opinion. The question is so important to New York City that it is hoped that provision will be made for further study.

The investigations of the Engineer Department give the only data for the tidal conditions in the Harlem River. From them it would appear that there is a resultant flow in the Harlem toward the Hudson. The Department is now making a further study of the question in connection with work contemplated for Hell Gate and its neighboring channels, Little Hell Gate and the Bronx Kills, and more data will soon be available. New sets of observations and measurements are needed near Old Ferry Point, at the extremities
of the Harlem River, in the East River, south of Hell Gate,
180 near the Battery, and in Buttermilk Channel, at the Narrows
and in the Sandy Hook Bar channels—sufficient to determine with greater accuracy the daily supply to and distribution in the harbor of the normal sea water.

The volume of fresh water discharge of the streams into the har-

bor is known approximately. Since the greater part of these streams must care for the sewage from a population along their basins, little or no help for the harbor can be expected from them. Care must be taken that they be not polluted to such a degree as to add to the work which the harbor waters properly may be expected to perform. To-day the Passaic flow is probably distinctly detrimental. If care be not taken that of the Hudson may soon be in the same condition. Newtown Creek and Gowanus Basin are notoriously septic and add to the harbor's burdens. Recent analyses of the Harlem waters show conditions at times nearly as bad. It is safe to say that the Passaic, Newtown Creek, Gowanus Basin and the Harlem are overloaded.

The oxygen supply from the rainfall can be calculated approximately. In a very large part of the drainage area the run off is collected in the sewers and this, with the excess of the drinking water supply, is available for useful work, excepting when the detention in the sewers is long enough to produce septic conditions and a waste of oxygen before discharge. These conditions undoubtedly exist in many of the older and badly designed sewers. In the City of Washington, for example, the character of the sewage effluent, collected at the disposal pumping station, is to-day remarkably fresh, due to the fact that in recent years, the older sewers of that city have been reconstructed and no long detention of sewage in them now exists. The contrast between the character of the Washington sewage and that of Boston, for example, is marked. In New York, the length of the sewers is generally short, and there is little or no reason why the time elapsing between collection and discharge should not be short. If it were, the work of the harbor waters would be diminished.

For convenience, what may be termed normal American sewage is assumed to be of a dilution equal to a consumption of 100 gallons of water per day per inhabitant. The absolute composition of sewage must vary for each locality and with the changing seasons, depending on the conditions of living, the proportion of manufacturing establishments per inhabitant, and other causes. But in the larger cities there is a degree of similarity in composition and, therefore, that what is termed normal American sewage, as described by Profs. Winslow and Phelps, can be taken as representative, for calculation, in the absence of exact information. It is evident that when water consumption is at the rate of more than 100 gallons per day per inhabitant, and when the rainfall is collected in the sewers the dilution is greater, and by that dilution is supplied oxygen which is available for sewage resolution. In New York to-day data is lacking. There is no record attainable of water consumption by districts; no record of the volume of sewer discharge, either per sewer outlet or per drainage area; no record of average sewage composition and little from which the population per drainage area can be computed. Such data is required for a satisfactory discussion of the problem of sewage disposal.

181 The determination of the supply of dissolved oxygen obtained by reaeration from the atmosphere is too difficult to admit of more than an approximation. Dr. W. E. Adeney, of Eng-

land, has propounded a certain hypothesis of the rate of reaeration of harbor waters, based on a series of laboratory experiments. His work is valuable in starting investigations into this subject, but his conclusions seem erroneous.

We are now engaged in further experimentation and investigation on the same subject. At best, however, little more can be learned than the probable rate of surface absorption of oxygen by still water and its rate of diffusion to the depths below. The important effects of wind and of surface agitation by passing shipping can only be guessed. Fortunately, these effects are beneficial, and if not overestimated may be considered a valuable factor of safety. Direct observations in the harbor itself would be of much value.

It is universally admitted that the harbor must not be permitted to reach a condition of pollution which will be detrimental to human health, or which will deter shipping from using the port. The exact degree of purity to be required has never been agreed on, nor is there any uniformity of opinion to-day as to what is the general condition of the harbor as regards allowable pollution. Localities are admittedly bad and costly provisions are being taken toward improving the local conditions in at least one of these, Gowanus Basin.

It is the belief of the writers that the waters of the harbor should be maintained in such a condition as to support major fish life everywhere, and that this condition requires that in no part shall there be found less than probably about 70 per cent. of the saturation quantity of dissolved oxygen.

When the importance of the subject and the vast amount of capital involved in the proper solution of the question are considered, it would appear self-evident that ordinary business sense would require the same careful investigation into existing conditions, into the necessity for a change, and into the most economical method of attaining the desired results, as is made for proposed betterments in private business undertakings.

The writers are endeavoring to find partial solutions to the problems with the limited resources available to them. They send you this letter in the hope that further interest may be awakened in this important subject and that a presentation of the problem as it appears to them, of the methods of solution suggested, and of the difficulties encountered may lead to a further discussion and to such official action as may permit a full and careful investigation to be made and a more accurate determination of the facts to be attained.

Very respectfully, W. M. BLACK.
EARLE B. PHELPS.

I hereby certify that the foregoing are true copies of reports presented to the Board of Estimate and Apportionment at its meetings on April 22, 1910, June 17, 1910, July 1, 1910, January 12, 1911, March 9, 1911 and March 23, 1911, and printed in the minutes (Public Improvement matters) of the meetings of the Board held on said dates.

W. H. LANG,
Secretary Board of Estimate and Apportionment.

June 20/12.

1 COMPLAINANTS' EXHIBIT No. 137.

James D. Maher, Commissioner.

4080.

Report on Sewage Disposal of Orange, Montclair, and East Orange.

James H. Fuertes, Consulting Engineer, New York.

October 14, 1911.

2 *Report on Sewage Disposal of Orange, Montclair, and East Orange.*

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3 NEW YORK, October 14th, 1911.

To the Joint Committee on Sewage Disposal of Orange, Montclair, and East Orange.

GENTLEMEN: Pursuant to your request I submit herewith a report on the disposal of the sewage of Orange, Montclair and East Orange, with recommendation as to the most suitable, efficient and economical plan to be adopted, together with estimates of cost of constructing the necessary works and keeping them in efficient and satisfactory operation.

Briefly, my recommendations are as follows:

1. That Orange, Montclair and East Orange unite in the construction and maintenance of a sewage purification plant at the site located partly in Bloomfield and partly in Belleville.

2. That the plant consists of grit chambers, Imhoff tanks, sprinkling filters, secondary Imhoff tanks and a sterilizing plant, costing, for construction, about $1,125,000.00, and for operation, excluding interest and sinking fund charges, about $22,500.00, and including these items about $95,000.00 per year.

3. That an arrangement be made by the three cities to perfect a joint administrative commission which shall have charge of the construction and operation of the works, and shall also have jurisdiction over the maintenance, cleaning and operation of the sewers of the three towns, including the main sewer leading to the disposal works.

4 Further, it is my judgment that there will be no difficulty in building and operating the plant recommended in such a manner that it will not produce disagreeable odors at the plant, or in its vicinity, or along the Yantecaw River Valley; or cause the Yantecaw River to be less desirable, at any time, for any

use to which it can now be put; or in any measureable degree increase the height of floods in the river.

The data upon which these recommendations are based will be found in the following pages.

General Description of the Territory under Consideration.

Orange, Montclair and East Orange lie on elevated ground from two to four miles west of the Passaic River, and to the north and west of Newark. Orange lies to the south of, and adjoins, Montclair, and East Orange to the east of and adjoining Orange.

Montclair has the largest area, about 6.1 square miles, but the smallest population of the three. The lowest ground in Montclair is near Bellevue Avenue, and is about 170 feet above sea level, in the branch of the Yantecaw River. The highest ground is on the mountain top, to the west, which is nearly 700 feet above sea level. Practically all the built up portion of the town lies lower than 400 feet above sea level, and the larger part between 250 and 300 feet. All the sewage from the town can be collected in sewers discharging by gravity to one suitably located point for treatment.

East Orange has an area of 3.91 square miles. The lowest land, which is near Grove Street at the northern end of the town, lies about 110 feet above sea level, and the highest, which is on Prospect Street between Park and Springdale Avenues lies about 190 feet above sea level. The sewage from East Orange can all be collected and delivered by gravity to a point near Second River convenient for connection with a trunk sewer laid to take the sewage from Orange and Montclair.

Orange lies to the west of and higher than East Orange, and its sewage is now brought down to Second River and discharged through the Union outfall sewers into the Passaic River.

The above brief description of the sewerage possibilities of these three communities is given to form a basis of the investigations for a joint disposal proposition. If any significant portion of the sewage of either of the three could not be delivered to a common point of outfall, for collection and subsequent conveyance to the disposal works, without pumping then the advantages of joint action would be less desirable. As it is, the sewage of all can be taken down the valleys of either the Second or Yantecaw Rivers without excessively heavy expense for the construction of the necessary sewers.

In the project which is recommended for adoption it is proposed to construct a new sewer, paralleling the present Union outfall sewer, (which serves Orange, Montclair and Bloomfield), from the junction of the sewer from Montclair to the site of the proposed disposal works in Belleville. This new sewer would be laid on a flatter, but self-cleansing gradient than the existing sewer, in order to deliver the sewage to the works at a high enough elevation to properly carry out the required processes. No pumping would be required to deliver the sewage from the three cities to the disposal works. The cost of the new sewer is included in the estimate of the cost of constructing the disposal works. The cost of the sewer from East Orange to con-

nect with the main outfall sewer is not included, as sufficient data were not at hand, on which to base an estimate.

6 Existing Sewerage Works and Character of the Sewage.

The sewers of Orange, Montclair and East Orange are all on the separate system, that is, they receive only sewage to the exclusion of rain water. A considerable amount of ground water, however, works into the sewers, and this will have to be taken care of at the disposal works.

The sewers of all the cities in this district have good slope: so that velocity of flow is great enough to keep them free from deposits.

The most distant buildings from which sewage will be conveyed to the point where the sewers from Orange and Montclair join is not more than four miles away from the junction, and with the velocities of flow that prevail sewage will reach this point in less than two hours after entering the sewers at the house connections. The sewage, therefore, will be fresh, not having had time in transit for the organic matter in it to begin to putrefy. So far as I have been able to find out, no offensive trades wastes enter the sewers in significant amounts.

To ascertain the actual condition of the sewage I have had samples collected for examination at a manhole on the joint sewer just above the tidal tank and these, together with the absence of odor at this point, where the sewage is violently agitated by falling into the manhole, confirm the conclusion that the sewage to be treated will not be in a putrescent condition when it reaches the plant. This will greatly simplify the problem of its purification.

At the present time the sewage of Orange, Montclair and Bloomfield is disposed of through the Union Outlet sewer extending down the valley of Second River, to the Passaic River. The Branch sewers from Orange, and from Montclair and Bloomfield, (which
7 use the same sewer) are each 24 inches in diameter. Below
the junction of these the sewer is egg-shaped, 2 feet, 4 inches wide and 3 feet, 10 inches high, there being, however, some 36-inch and some 30-inch stretches, including river crossings. From the tank to the outlet into the Passaic, a distance of some 3,800 feet, it is of cast iron 48 inches in diameter.

Quantity of Sewage to be Provided for.

Based upon the available data, the sewage originating in the three cities, which are of the same nature as to occupancy and commercial interests, should average about 100 gallons per capita.

The sewage does not flow through the sewers at a uniform rate throughout the twenty-four hours, or at the same rate on different days; from general experience it is found that the least flow is about 2 or 3 o'clock in the morning, increasing to a maximum about 9 to 10 o'clock in the morning, then decreasing towards noon and rising again about 2 in the afternoon, and that the maximum rate of flow to be expected will be from one and a half to two times the average rate of flow. Since there will be no storm water to be taken care of

in the system the works can be designed to accommodate the quantities of sewage that will result from the populations given in Table I, with an additional allowance to provide for the ground water entering the sewers.

Daily gaugings of the depth of flow in the sewers from Orange, and from Montclair and Bloomfield, have been kept since 1894, for the purpose of apportioning the cost of maintenance of these sewers among the cities using them, payment being made on the basis of relative use. A study of these gaugings which were placed at my disposal by Mr. Crane, City Engineer, of Orange, N. J., shows that a very considerable percentage of the total flow is ground water which leaks into the sewers. An analysis of these records indicates
8 that the ground water flow varies from season to season
through a wide range. For instance, during the first 7 months of the year 1908 both sewers ran entirely full, for the entire period, and at times were much over-taxed. During the past 8 months of 1911, however, they have run about 2/3 full most of the time, and entirely full for about a month. As nearly as I can estimate the minimum ground water flows in these two sewers together has been about 4,000,000 gallons per day and the maximum in excess of 7,000,000 gallons, or, reduced to leakage per square mile of sewered area, the figures would be about 280,000 gallons for the smallest rate and over 490,000 gallons per square mile per day for the greatest. Adjusting these figures to the cities of Orange, Montclair and East Orange the quantities of ground water to be taken care of at the disposal works would be about 3,500,000 gallons daily for the ordinary dry weather flow, and 6,000,000 gallons daily for wet weather flow, the latter rate persisting for possibly half a year at a time. For shorter times rates reaching nearly 9,000,000 gallons daily are likely to be reached.

The past, present and estimated future populations of Orange, Montclair and East Orange are given in Table I.

TABLE I.

Populations.

City.	Areas. Sq. miles.	Populations. 1900. U. S. Census.	1910. U. S. Census.	Estimated For 1925.	For 1940.
Orange	2.22	24,141	29,630	45,000	60,000
Montclair	6.10	13,962	21,550	35,000	50,000
East Orange.......	3.91	21,506	34,371	53,000	70,980
Totals.......	12.23	59,609	85,551	133,000	180,980

Disposal works should be built of sufficient capacity to pro-
9 vide for some years in advance of the present, so as not to
require extension immediately. On the other hand, it would not be economical, either as to cost of construction or efficient operation to build them large enough to serve populations that will not

be reached for more than a generation. In my judgment works large enough to take care of the population that may be expected by 1925 will be as large as should be built at present, as this will give sufficient margin of capacity to permit extensions to be made, should the population increase more rapidly than estimated above, in ample time to provide for the increased population. On the other hand, the main sewer leading to the works, which would be costly to duplicate, should be large enough to take care of the maximum rate of flow to be expected by 1940.

Based on the populations given in Table I., and on the assumption that, on account of the considerable time that some of the sewage will require to reach the disposal works, the maximum rate of sewage flow will be 50 per cent. in excess of the average rate, the maximum quantities of sewage that would reach the disposal works, in 1940, from the three cities, including ground water, would be as given in Table II.

TABLE II.

Estimated Maximum Rate at which Sewage Will Reach the Disposal Works in 1940.

Million Gallons Daily.

City.	Constituent parts of sewage.			
	House sewage (150 gallons per capita).	Ground water 700,000 gallons per sq. mile daily.	Trade wastes.	Total maximum rate of sewage flow.
Orange	9.00	1.82	0.85	11.67
Montclair	7.50	4.31	0.01	11.81
East Orange	10.65	2.74	0.09	13.48
Totals	27.15	8.87	.95	36.96

For the average conditions of flow that may be expected in 1925, the figures would be given in Table III.

TABLE III.

Estimated Average Rate at which Sewage Will Reach the Disposal Works in 1925.

Million Gallons Daily.

City.	Constituent parts of sewage.			
	House sewage (100 gallons per capita).	Ground water 280,000 gallons per square mile.	Trade wastes.	Total.
Orange	4.50	.62	.26	5.38
Montclair	3.50	1.70	.01	5.21
East Orange	5.30	1.09	.03	6.42
Totals	13.30	3.41	.30	17.01

On the above assumptions, therefore, the capacities of the principal divisions of the works should be able to accommodate the quantities of sewage estimated as follows:

The main outfall sewer to the disposal plant, and the main outlet pipe from the works, the maximum rate of sewage flow from 181,000 people, amounting, including ground water flow, to 37,000,000 gallons per day, the sewer to run three-fourths full with this quantity of sewage.

The disposal works, the average rate of sewage flow from 133,000 people, amounting, including ground water, to 17,000,000 gallons per day, the works being so laid out as to permit of extensions, when necessary, to provide for receiving the sewage from a population of 181,000 people, amounting, including ground water, to an average rate of flow of 23,000,000 gallons daily.

11 Although the average rate of flow of the sewage in 1925 will be about 17,000,000 gallons daily there will be times when the rate will reach about 23,000,000 gallons and the works will have to take care of it as it comes. By proportioning the plant properly the increased rate necessary for a few hours daily will not injuriously affect the character of the effluent, as the processes to be used are flexible enough to secure satisfactory results within these limits.

Methods of Disposal of Sewage.

Sewage from cities like Orange, Montclair and East Orange, consists of water carrying away, partly in suspension and partly in solution, the wastes from the houses and buildings of the people. About 999 parts out of a thousand, by weight, of the sewage, are clean water, and it is the organic portion of the one part, (which latter is about half mineral and half organic matter) which, by decomposition and putrefaction gives rise to foul odors and nuisances. The construction of purification works, of considerable cost, therefore, is made necessary by a relatively small amount of putrescible organic matter in a very large amount of water, and the problem is one of removing this small amount of organic matter from the water, or destroying it, or changing it before putrefaction sets in to a form in which it will not subsequently become offensive.

Generally speaking the process, for economical and practical reasons, must be done in two stages, the first being to remove quickly, before decomposition sets in, by subsidence, screening, filtering, or combinations of these, as large a part of the suspended matters from the sewage as advisable under the condition prevailing. These suspended matters consist of silt, sand, coagulated clay, fibres and pieces of paper, rags wood and resistant solids, particles of excrement, scraps of meat, vegetables and other refuse from houses, markets, and factories.

12 The second stage in the treatment is to oxidize or destroy those portions of the wastes in solution, and of the solids in suspension, particularly those of an organic origin, too small to be removed by the processes available for the first stage of the treatment, and to destroy and eliminate the bacteria which accompany the

organic matter in the sewage and which pass through the first stage of treatment without being reduced materially in numbers.

The first stage of the treatment is essentially mechanical, as the work must be done quickly in order to keep the sewage fresh and inodorous when it undergoes the second stage of treatment, which is essentially chemical, although the resulting chemical changes are largely brought about by living organisms.

For the first stage two operations are necessary, the first being to separate the suspended matters from the liquid sewage and the second to dispose of these suspended particles after they have been removed. The first stage is necessary for the reason that if not carried out the second stage would fail by the clogging of the works, with resultant putrefaction and nuisances which might necessitate the reconstruction of the works. When the first stage is efficient the second is easy of consummation; and the more efficient the first the greater the success and efficiency of the second.

The extent to which the purification of the sewage must be carried in any case depends upon local conditions. When an outlet can be had to the open sea, or to a great river whose flow is large enough to disperse, dilute, and purify it, no treatment is necessary save perhaps screening and the removal of sand. Where the outlet is into a small stream running through pasture lands, or serving as a water supply or ice supply for inhabitants in the vicinity, the sewage must be purified to as high a degree, and to as uniform a quality, as possible of attainment.

13 The processes available for the first stage, stated in the order of their efficiency in the removal of suspended matters from the sewage are: coarse screens; fine screens; ordinary settling basins, operated with or without chemicals; slate beds; specialy designed settling basins (such as the Dortmund and Imhoff tanks); and especially designed, rapidly operated filters in connection with special forms of settling basins.

Coarse screens will remove only large particles and floating matters. Fine screens will remove a somewhat larger percentage of such matters, but fail to intercept the finest particles of silt and mud in suspension. The particles removed by screens are disposed of by burning or burying.

Ordinary settling basins, when well designed, will largely remove the suspended matters, which require frequent removal to avoid nuisances. The sludge resulting from deposition in such basins is great in amount and difficult to dispose of owing to its large percentage of water and the slowness with which it dries out. Its disposition is effected, when no chemicals are used, by draining it off into lagoons to dry out, and then digging it out and hauling it away; or plowing it into the ground where this is feasible, or discharging it into tanks, or trenches, to "work" or digest, and after reaching a proper condition, digging it out and hauling it away; or, where chemicals are used, passing it through so-called filter presses to squeeze out the water, using the resulting cakes of pressed sludge for filling low ground, or otherwise disposing of it.

Mr. J. W. Dibden, of London, has in recent years introduced in

many places special settling basins containing layers of slate arranged to facilitate the deposition of the solids and their digestion in an inodorous manner. The efficiency of such beds, so far as the effluent sewage is concerned, is about the same as of septic
14 tanks, and its disposal involves about the same problems. The humus, or sludge, however, from such beds, when these are properly designed and operated, is inodorous and smaller in quantity than from ordinary settling basins. The cost of the beds for many locations, however, would be great in comparison with other processes producing under ordinary conditions equally good or better effluents.

Specially designed settling basins, such as the Imhoff tank, so-called in honor of Dr. Karl Imhoff, of Essen, who perfected it, will remove as large a percentage of the suspended matters from the sewage as can be economically taken out by subsidence, and at the same time reduce these deposited matters to an inoffensive condition of smaller volume than deposits from similar sewage in ordinary settling basins; further, the condition of the sewage itself as to freshness is not altered while passing through the tanks.

Specially designed rapidly operated filters, in connection with specially designed settling basins, will remove practically all of the suspended matters, and when operated in connection with chemicals, a portion of the dissolved organic and mineral matters, and give a clear effluent, and one that could be discharged into relatively smaller streams, without fear of nuisance, than the other preliminary processes. The matters removed from the sewage by the filters would be passed back to the settling tanks to be digested with the matters deposited from the sewage therein before reaching the filters.

The removal of the deposits from the specially designed settling basins, in these two last mentioned processes, would be accomplished by emptying it from the bottoms of the tanks upon shallow beds of fine gravel where the water would drain out and permit the sludge to dry out. The dried sludge would be removed and disposed of on low ground in the vicinity, or wherever convenient. Sludge removed from such tanks dries readily. Its water content is much less
15 than that of sludge removed from ordinary settling basins, and when discharged upon beds for drying is charged with inodorous gases, evolved during its digestion in the tanks, which makes it light and porous, permitting the water to drain out readily.

Other preliminary processes for the removal of the suspended matters, being modifications and combination of the above, are in use at various places at home and abroad, but the methods outlined elucidate in a broad way the principles underlying all the methods in practical operation.

Among the modifications may be mentioned one wherein the sewage is retained in the settling basins for a long enough time to allow putrefaction to begin, with the aim of thereby reducing the quantity of sludge to be handled, by causing some of the solids to go into solution and be carried out of the tank with the sewage. Tanks of this sort are called septic tanks and a few years ago were introduced extensively. Owing to the difficulty of disposing of the effluent from the tanks, which generally smells badly, their use is now limited

to special situations and conditions. Another modification is the use of coarse grained filters, operated at a rather high rate, to serve the purpose of very fine screens. Such filters, however, are usually short lived, unless elaborate provisions are made for keeping them cleaned, otherwise when they become clogged the filtering materials require removal and replacement.

It will be seen, therefore, that a decision as to the proper method of preparatory treatment to be adopted will depend upon the method of secondary treatment necessary, and this must be adjusted to give the character of effluent desired from the plant.

The more prominent and widely used forms of secondary treatment are:

16 1. The treatment of the sewage with chemicals which assist in producing a relatively rapid and extensive deposition of the solids in suspension. and the removal of about half of the organic matters in solution.

2. The disposal of the sewage by using it to irrigate large tracts of land, either for raising crops of various sorts, or for getting rid of it. This process requires a large area of land, and has the disadvantage that during rainy weather, when the ground is soaked with water, the sewage can not be taken care of so readily, and ponding is apt to result.

3. Passing the sewage through contact beds. These are tanks containing relatively coarse granular materials, through which the sewage is passed in a manner to bring it in contact with the air entrained in the bed and allowing it to stand for a certain length of time to produce the necessary oxidation and bacterial action; the sewage is then emptied out, either to a second set of similar beds or to its final place of discharge, depending on the degree of purification desired. Such beds, when properly designed and operated, are inodorous, produce excellent results, giving an effluent acceptably clear and oxidized to a condition of stability, that is: rendered non-putrefactive. Generally, however, such beds eventually partially clog up with the sewage matters deposited therein and the filtering matters have to be removed and new ones put in their place. The relative permanency of such beds depends upon the fineness of the materials and the extent to which the preliminary process used removes the suspended matters.

4. Spraying the sewage over deep beds of coarse granular materials. Such beds are called sprinkling filters. Sprinkling filters, when properly designed and operated, will oxidize the organic
17 matters in solution in the sewage, as well as the fine particles
in suspension to a stable or non-putrescible condition. The effluent from such filters, however, is not clear, as the clay, silt, etc., is not retained by the coarse-grained materials forming the bed. Their life depends upon their ability to unload or discharge the matters temporarily retained therein after their conversion to a non-putrescible condition. Generally, therefore, further treatment is necessary to remove the suspended matters from the effluent, and this may be done by subsidence, by passing it through contact beds, or by filtration through specially designed filters, the water used in

washing which would be discharged back into the raw sewage entering the preliminary treatment works. Contact beds for this purpose offer the disadvantage of gradual loss of capacity by clogging, and of changing unfavorably the chemical character of the effluent from the sprinkling filters, when this has to be discharged into streams and ponds.

5. Filtration of the sewage through specially prepared beds of sand by applying it to the filters intermittently in doses no larger than the character of the sewage and construction of the beds will permit to secure the oxidation of the organic matter and removal of the bacteria. When properly designed and built such filters will purify the sewage to a very high degree, yielding an effluent clear, non-putrescible and freed from a very large percentage of the bacteria. The necessary works, however, are generally expensive to build, particularly when the beds have to be artificially constructed of sand brought from a distance; further, they must be operated with intelligence to keep them in an active and efficient condition.

18 In some cases it is necessary to carry the purification to still greater lengths than can practically be obtained by any of the above mentioned processes, and in such cases the effluent from the works can be sterilized, after being rendered clear and non-putrescent, by the use of some sterilizing agent, such as hypochlorite of lime or soda, or by the use of ozone, which can be prepared from the air by electrical treatment.

Available Sites for Disposal Works.

The method of disposal that will be best suited to local conditions will depend upon the sites available for the works.

After looking over the situation with much care I have found but two localities where works could be located. These are:

1. The site selected and now controlled by the cities interested, which is located in the northwest corner of the Town of Belleville, and northeast corner of Bloomfield.
2. One of two sites on the meadows of the Hackensack River.

The second mentioned sites, while suitable for the construction of the works, are far away and lie beyond the hill which separates the Passaic River Valley from the Hackensack Meadows and to utilize one of these would necessitate building and maintaining a pumping station to elevate the sewage over the hill; and to utilize the other, resorting to pumping, or to the use of an inverted siphon to get the sewage over the 60-foot hill east of the Passaic River, in addition to constructing several miles of large trunk sewer, for either site. The cost of pumping the sewage, without interest, depreciation and sinking fund charges on the cost of the sewer and pumping station, would, for the lower site, be upwards of $40,000.00

19 per year, which would represent, at 5% interest, a capital investment of $800,000.00, and would make the project less desirable from a financial standpoint than the Belleville site, as practically the same character of effluent would be required from the works in either case in order to avoid, in the case of the meadow site, the pollution of the Hackensack River and Newark Bay. The use

of the upper meadow site, with an inverted siphon under the Passaic, while possibly practicable, would involve much expense for construction, and some difficulties in operation, which can be avoided at the Belleville site.

This being the case the problem in hand becomes one of determining the character of effluent required from works situated at the Belleville site, and the conditions that must be fulfilled with respect to the avoidance of nuisances locally.

Character of Effluent Required.

The tract of land chosen for the location of the disposal works lies along the south bank of the Yantecaw, or Third River, the effluent from the proposed plant must be discharged into this stream. In order to design the works, therefore, it will be necessary to know the conditions of flow that prevail in the stream at different seasons, the topographical, meteorological and geological features of the district, the character of the country through which the stream flows as to occupation for residences and manufactories and the probabilities for future growth and improvement for these uses that would be affected by the construction of the works.

Immediately below the proposed site is a shallow pond some 2,000 feet long formed by a dam about 2,300 feet up stream from Harrison Street. A little over a mile further down is another dam, the back water extending up to within about a mile of the first men-
20 tioned pond. Three-fourths of a mile below the second dam is a third forming a pond about 2,000 feet long, furnishing power to a paper mill, and three-fourths of a mile below this is a fourth, which supplies two mills, the larger of which is a bleaching mill. The back water from this pond reached up to within half a mile of the third dam. There are no other dams on the stream before its junction with the Passaic opposite Lundhurst. Between the ponds formed by these dams the stream is in some places swift and others sluggish, winding about the valley through a shallow channel with low banks bordered by grass lands, lawns and fields, and some marsh lands. Generally speaking the banks are covered with underbrush and the channel more or less obstructed with growths of various sorts although some portions have been straightened and cleaned out.

For about half a mile below the proposed works to below Nutley, and Franklin, the stream flows through a well built up suburban residential district containing many fine properties, to some of which the creek in a clean wholesome condition is a valuable asset while in an unclean condition would be not only a nuisance but a damage of serious proportions. The water of the creek is not, and should not be used for a domestic water supply, whether the proposed sewerage works are built or not, and should not, whether it is now so used or not, be taken as an ice supply for the people of the vicinity, so that for these purposes the effluent from the proposed works, if of a high enough purity, would not damage the stream.

There are clear indications that in the future the district through which the stream runs will continue to improve, and that the popu-

lation resident in the valley and surrounding hills will increase, probably more rapidly than it has in the past.

A comparison of the sewage flow from 181,000 people (the
21 estimated population 1940) to the estimated natural flow of the stream, which has a watershed area of about 8.6 square miles above the site of the proposed works, is given in Table IV.

Table IV.

	Estimated flow of Yantecaw River, in million gallons daily.	Average rate of sewage flow in 1940, in million gallons daily.
Minimum daily flow of river	0.7	23
Minimum monthly flow of river	1.0	23
Flows for average year:		
Driest month	3.8	23
2nd driest month	4.0	23
3rd " "	4.2	23
4th " "	4.7	23
5th " "	6.6	23
6th " "	8.0	23
7th " "	9.5	23
8th " "	11.7	23
9th " "	13.6	23
10th " "	13.9	23
11th " "	14.2	23
Wettest month	14.3	23
Frequent flood flow	200.0	23
Large flood flow	430.0	23
Maximum flood flow	1200.0	23

It is evident, from this Table, that the character of the effluent from the plant must be of a high order, as the sewage flow, even when the plant is first put in operation, will average greater in amount than the average natural stream flow throughout practically the entire year.

During ordinary floods, which occur with frequency, the sewage flow will not have any noticeable effect towards raising the flood heights, and this effect will diminish with the intensity of the floods.

If the sewage is purified to a high enough degree, however, the effect of its discharge into the stream will be beneficial by causing a more copious and uniform flow throughout the year. All the sewage reaching the works, therefore, would have to be purified to a very high degree.

22 The water of the Yantecaw River is now somewhat discolored and polluted by manufacturing wastes, but is not very offensive, as no great quantity of sewage enters it.

Its velocity, however, is rather sluggish throughout most of its length, owing to the presence of the dams above mentioned, which

have been in existence for many years for furnishing power and for other uses.

Summing up, it can be seen that to fulfill the necessary conditions the effluent from the proposed works must be free from suspended matters, clear, free from odors, free from matters in solution that would putrify and cause disagreeable odors, and free from constituents that would cause troublesome growths in the stream and ponds, especially during times when the water would naturally be clear. It is also necessary that the removal of the bacteria from the effluent should be great enough not to cause added pollution to the stream, particularly with respect to those forms which contribute to, or cause, water borne diseases. In other words, the effluent from the plant should always be in as good or better condition than the natural flow of the stream.

Other conditions, however, must also be fulfilled by the works and these relate mainly to the simplicity of the plant, its reliability and its flexibility in dealing with varying quantities of sewage flow without diminution of efficiency, and without causing offensive odors or other nuisances at the works, or in the stream below the works.

Type of Plant Best Suited to the Site Selected.

From surveys which have been made by Mr. Crane, City Engineer, of Orange, N. J., it appears that the invert of the main sewer can be placed at an elevation of 89.5 feet above sea level at the disposal works. The elevation of the surface of the sewage in the
23 sewer, at the works, at minimum flow, will be, therefore, 91.5
feet above sea level. As the water in the Yantecaw River at ordinary stages is 72 feet, the available head for passing the sewage through the plant will be 19.5 feet, which is sufficient for the purpose.

In the matter of purification it is best to consider first the most suitable method of final disposal and then select the method of preparatory treatment that will be best adapted to prepare the sewage for final treatment.

Broad irrigation is out of the question as there is not enough land available for the purpose. It would probably require about 2½ square miles of land, with soil of the kind common in that locality, to properly assimilate the sewage, and the cost of maintenance would be greater than any possible revenues that could be had from crops that could be successfully grown on the area.

Chemical precipitation would be unsuitable, unless followed by, or combined with other processes, as the effluent, although clear, would still contain enough organic matter to putrefy and cause a nuisance.

Contact beds, particularly if used in series so that the effluent from one set of beds would pass through a second set before discharged into the stream, where the method can be used, will give a stable effluent of good purity and the works can be maintained without nuisance. In order to use this method successfully the sewage must be delivered to the works at a high enough elevation to permit of the construction of the works, using a sufficient depth of filtering

materials to effect the proper purification, and allowing sufficient extra head to operate the mechanisms necessary to discharge the sewage into each set of beds and permit them to drain out again before the next filling. A further requirement is that provisions must be made in the maintenance charges for renewing the filtering materials at greater or lesser intervals of time, owing to the reten-
24 tion therein of the accumulating, unchangeable mineral matters. Double contact beds could not be built at the available site without pumping all the sewage up to a higher elevation than that to which it can be delivered by gravity, and the cost of construction and annual cost of operation would be greater than for sprinkling filters.

Sprinkling filters can be built at the site selected, and will give an effluent that will not subsequently putrefy. It will, however, in order to render it clear, require further treatment to remove the suspended matter, and also may require sterilization, as the bacterial purification of such filters is not high. For rendering the effluent from the sprinkling filters clear two plans are available, one being subsidence in settling basins and the other filtration through specially constructed rapidly operated filters. The filters would produce a brighter effluent than the basins, but at greater cost for construction and operation. Furthermore, at the site selected there would hardly be head enough available for their operation without pumping.

Settling basins of the Imhoff type, if properly designed for this work, would give excellent results in the final clarification of the effluent, particularly if operated in connection with chemicals to assist in hastening the work. Recent experience in Germany has shown that chemicals can be used in this connection without interfering with the efficiency of the tanks in sludge digestion.

The combination of secondary processes to produce a clear, nonputrefactive effluent, therefore, would be sprinkling filters followed by subsidence in specially designed Imhoff tanks.

For the preparatory process there is not sufficient head available to use either coarse grained filters or slate beds. Ordinary settling basins could be used, but the removal and separate treatment
25 of the sludge depositing upon the bottom would involve difficulties and nuisances. Imhoff tanks appear to be the only available form of tanks that can be adapted to the location. These will remove enough of the suspended matter from the sewage to permit of satisfactory results with the sprinkling filters, and they solve the question of sludge reduction and removal more satisfactorily than any other process with which I am familiar. The sewage flowing to the tanks will need no further treatment than to pass through coarse screen bars, placed about 2 inches apart, and thence through a shallow, widened section of the sewer channel in which the velocity of flow will be reduced to about 1 foot per second. This channel should be long enough to give time for the silt and sand, which enters the sewers through the perforations in the manhole covers, to settle down upon the bottom.

To secure the necessary bacterial purification of the effluent, from the secondary settling basin, before discharge into the Yantic

River, a solution of hypochlorite of lime, or some other cheap form of sterilizer may be used.

The arrangements for using the sterilizing solution should be planned so that it could also be introduced into the effluent from the first Imhoff tank before it reaches the sprinkling filters, if desired, to prevent troublesome growths in the filters. These have occurred in certain plants, and have been cleared out and their return prevented in this manner.

Briefly, then, the type of plant best adapted to secure the quality of effluent necessary would consist of:

1. Coarse screens, about 2 inches apart.

2. Deposit chamber for silt and sand, in which the velocity of flow would be reduced to about 1 foot per second, the chambers to be 75 to 100 feet long, to secure the deposition of sand and
26 silt. This can be provided for by having three such chambers, so that one or all could be used, depending upon the volume of sewage flow and character of the sewage.

3. A set of Imhoff tanks for the removal of the suspended matters and the digestion of the sludge, the settling compartment of the tanks to have sufficient capacity to hold three hours' flow of sewage at the average rate, and the sludge compartment large enough to hold six months' accumulations of sludge. There would be 12 tanks, each about 27 feet deep and 100 feet long, in the direction of flow, holding a volume of about 4,420,000 gallons, and covering, including the channels between the beds about 1.15 acres.

4. Sprinkling filters to oxidize the organic matter in the effluent from the tanks to a stable, or non-putrefactive condition. These should have sufficient area to handle the average flow of sewage at a rate not greater than 2,000,000 gallons per acre of filter surface, per day, and could be arranged in two units, covering, including space for chambers, about 8 acres, or a tract about 500 feet wide and 700 feet long. The sewage would be sprayed over the beds from dosing tanks operating under heads varying from 2½ to 6 feet. The beds would be built up to a depth of about 8 feet of stones varying from 1½ to 2½ inches in diameter.

5. A second set of Imhoff tanks, to allow of the subsidence of the suspended matters from the effluent of the sprinkling filters, to hold about two hours' flow of sewage and to be operated with or without the use of chemicals to aid the settlement, depending upon the character of the sewage being treated, and being constructed with sludge chambers holding about 10 days' accumulations of sludge, the deposits in which would be pumped back to the first set of
27 Imhoff tanks intermittently, as required. These secondary tanks would be about 15 feet deep and 95 feet long in the direction of flow, arranged in 12 units having a total volume of about 2,000,000 gallons and covering an area of about 0.75 acre.

6. A chemical dosing house in which to prepare the sterilizing and precipitating chemical solutions, should it be necessary to use either one or the other or both together. The piping arrangements from this house should permit the discharge of any of these solutions, either into the sewage as it goes upon the sprinkling filters, or

into the second set of Imhoff tanks or into the effluent from these tanks before it goes into the river.

7. With the primary Imhoff tanks will also have to be arranged sludge beds for draining the water out of the sludge, and places for disposing of the sludge thus removed. The sludge beds will require an area of about one acre and should be well underdrained and covered with a surface layer of fine material.

The arrangement of the Disposal Plant, of course, is subject to modification after detailed surveys and borings have been made and after sufficient study has been given to the subject to work out the most economical plan.

Method of Operating the Plant and Results of Operation.

As before stated, the sewage will arrive at the plant in a fresh condition and will consist of ordinary town sewage diluted with clean ground water. The underlying principle in the design of the plant must be to keep the sewage in a fresh condition while separating from it the suspended matter and changing the dissolved organic contents into a non-putrescible condition. After this part
28 of the process is completed the matters temporarily retained
in the sprinkling filters (which from time to time are washed out and cause the effluent to be somewhat turbid) must be separated therefrom and disposed of; and finally, if necessary, the escaping clear water must be sterilized. Further, the deposits that take place in the Imhoff tanks must be disposed of in a satisfactory manner, and there must be no odors about the place that would cause offense to people living in the neighborhood of the plant, or along the stream below.

Screens.

The screens for the plant should consist of iron bars placed in the inlet channel to the plant, about 2 inches apart and sloping at an angle of about 20° to the horizontal. These are intended to intercept and permit the removal of tin cans, bottles, boxes, boards, bricks and other large floating or heavy matters which would obstruct the slots, or the sludge outlet pipes from the Imhoff tanks. These matters removed from the fresh sewage will be small in amount, and can be readily disposed of without nuisance by burying, burning or other commonly used methods.

A photographic view of the usual type of screens employed for this purpose is shown in Figure 5.

There should be no odor whatever about this part of the works if the superintendent takes the trouble to keep the place clean.

Grit Chambers.

A velocity of flow through the grit chamber of 1 foot per second will deposit the sand, but none of the organic matter; this latter will all go to the tanks for subsidence and decomposition. Ordinarily there will be no grit or sand in the sewage. After heavy rains

a certain amount may wash in through the perforations in
29 the manhole covers in the streets of the town. This will be
caught in the grit chambers and can be removed, as necessary, without nuisance. It will not give offense when dumped on the low ground below the plant, and after draining out and being rained on a few times will purify itself of the small amount of organic matter it contains, and can then be used for renewing the top surface of the sludge draining beds for the Imhoff tanks.

Imhoff Tanks.

The Imhoff tanks should be designed to give the sewage about three hours to deposit its suspended matters, and with sufficient room in the sludge chamber beneath to hold about six months' accumulations of sludge.

The plant would include 12 of these tanks. Each would consist of a settling chamber, with a sludge chamber beneath it, so arranged that the solids which are deposited in the settling chamber will slide down through a slot in the sloping floor to the sludge chamber beneath, the slot being arranged, by lapping one edge over the other, so that while the solids can pass down the gases that form when the solids decompose in the lower chamber can not rise up into the fresh sewage passing through the settling compartment over head. Scum-boards and baffleboards would be placed in each settling compartment to intercept the floating matters and secure as uniform and perfect subsidence as possible. Each tank would be arranged with inlet and outlet pipes and necessary control gates so that the sewage could be passed through the tank from either end, at will, and fill the sludge chambers uniformly. From each sludge compartment a valve-controlled emptying pipe would permit emptying the sludge upon the drying beds, as desired. Perforated water
pipes would also be installed in the sludge chambers, at the
30 bottom and along the sides to assist in loosening up the sludge
before emptying and to permit its agitation, if required, and a connection would be made to the sludge emptying pipe so that after emptying a tank all the sludge left in the pipe after closing the valve could be blown back into the tank and thus leave the pipe full of clean water.

The tanks should be built of concrete with very smooth surfaces and steep slopes and all the channels leading to and from them should be open and smooth so as to permit of keeping them perfectly clean and free from deposits.

In the construction of the tanks ample room should be provided for the floating matters that rise up from the sludge compartment and form a crust, or scum, over the surface.

Tanks of this type can be made either circular or rectangular in form, as best suits local conditions of economical construction, and are usually about 30 feet in depth, with conical or pyramidal shaped bottoms in the sludge compartment to keep the sludge together during its rotting. A general view of the tanks at Essen-North receiving the sewage from 180,000 people is shown in Figure 1.

During operation the sewage passes through the tank in a continuous stream, which is not interrupted thereafter, the solids in suspension settling to the bottom and sliding through the slot to the sludge chamber below. As great a proportion of the solids as can be removed economically by subsidence will drop to the bottom compartment in from one to three hours, depending upon the nature of the sewage. In some of the plants in successful operation only one hour's subsidence is necessary, while in others a longer time gives better results. Generally speaking, the proportion of the solids that can be removed from ordinary sewage, by subsidence, in periods longer than 2 hours, is so small that it does not pay to expend the necessary capital to secure the slightly higher percentage re-
31 moval, particularly as the processes adapted for further treatment can receive and treat one effluent as well as the other; and the more quickly the sewage can be passed through the settling tanks, to produce an effluent suitable for the second treatment, the less the risk of having offensive conditions about the plant.

The solids which settle out of the sewage in transit through the settling tank collect in the bottom of the sludge compartment and undergo decomposition, until reduced to a slimy black material resembling peat mud. It takes several months for this process to be completed; and the tanks, therefore, require sufficient sludge space for this to occur. Generally no sludge is drawn out of the tanks, after first being put in operation, for three or four months, or longer, depending on the rapidity and completeness with which its decomposition has gone on. After the tanks have been in operation for several months, however, the sludge is removed at more or less frequent intervals to make room for the new materials continually being deposited. The times of drawing out sludge can be accommodated to weather conditions, the sludge being allowed to accumulate, during very cold, or wet, weather until favorable conditions occur to facilitate its drying.

During the decomposition of the sludge various gases are evolved, the principal of which are carbon dioxide and marsh gases, the same that can be seen coming up through the water in swampy places where leaves, grasses, roots and other organic matters decay under the water. These gases have no appreciable odor and are liberated in too small amounts from the tanks to be detected in the air after liberation from the surface of the lisuid. The absence of the odor of sulphuretted hydrogen, which smells like rotten eggs, and is usually the principal source of nuisances from decomposing organic matter, whether garbage, sewage or other similar mat-
32 ters, is one of the marked characteristics of the decomposition which takes place in these deep settling tanks. No explanation has yet been given of the phenomenon, but that it is a fact can be attested to by all who have visited the many such tanks in operation in the Emscher Valley where they were first built and are now being introduced in increasing numbers.

It has been suggested that the absence of the odor of sulphuretted hydrogen might be due to the presence of iron, in the sewages being treated in the Emscher district, with which the sulphuretted hydro-

gen would combine and thus not be liberated as a gas, but the fact is that some of the tanks are receiving sewage of a purely domestic nature, which show, on analysis no iron, as successfully as others which contain it in large amounts. At the experiment stations established by the Cities of Philadelphia and Chicago the same results have been secured as in the Emscher district in Germany, in this regard, and the sewages treated show on analysis no more iron in solution than average normal American town sewages.

It is to be noted that non-odorous decomposition does not begin at once, but only after the tanks have been in use for two or three months. When a tank is first filled with sewage the sludge chamber, as well as the settling compartmest fills with sewage until it rises up high enough to flow out of the overflow from the tank. The whole sludge chamber is thus filled with sewage which can not get out again, and the organic matter in it, both in suspension and in solution, has to decompose and rot. During this period there may be occasions when more or less odor will be noticeable about the tanks, particularly during hot, humid weather. After this first sewage has once decomposed, however, no further odors come from the tank when in normal operation, and the water in the sludge chamber, above the sludge, is practically clear and non-odorous, and
33 covered with a crust or scum from which the only odor is a faintly tarry smell which can be detected only by turning the scum over with a fork and placing the nose close to it. At least this has been my experience at these works. After a state of equilibrium has been reached no more fresh sewage enters the sludge compartment excepting such quantities as may be required to make up for the volumes of sludge drawn out from time to time.

Owing to the method of constructing the tanks the gases which are evolved in the sludge chamber, in excess of what the liquid in the chambers will dissolve at the prevailing temperatures and pressures where dissociated during decomposition, rise up through the liquid and are deflected by the underside of the sloping bottom of the settling compartment, and issue to the air through the sludge space without passing through the fresh sewage flowing through the settling compartment. This prevents the contamination of the fresh sewage with the rotting particles carried up by the bubbles in the sludge chamber and allows the settled sewage to flow through and out of the tank still in a fresh condition.

Sometimes, particularly after having been in operation but a short time, and when silt and sand are allowed to go into the tanks, the sludge solidifies in the bottom of the sludge chamber and the liberated gases, accumulating thereunder, lift large pieces up which may choke the slot and prevent the entrance of the solids deposited from the fresh sewage. When this occurs it is necessary to draw off some of the partly decomposed sludge and clear the slot; this operation is attended with more or less odor, but is a condition which rarely occurs and which can be prevented by an alert attendant, and, if occurring, can be remedied by simple and effective measures. It does not occur in well designed and properly operated tanks.

The formation of gases in the sludge chamber is of much
34 importance in facilitating the handling and drying of the sludge. As is well known, the quantity of gases water will dissolve, other things being equal, is proportional to the pressure. The gases which are liberated in the bottom of the tank are dissolved under a pressure of about 30 feet of water, or about one atmosphere in addition to the atmospheric pressure. When this water, containing the gases dissolved under this pressure, is brought up to the surface at atmospheric pressure, the gases can no longer be held in solution and are occluded in the form of fine bubbles. The ordinary siphon of carbonated water is a familiar example of this phenomenon. These waters are charged with carbonic acid gas under heavy pressure and the water takes the gas in solution. As soon as some of the water is drawn from the siphon the pressure of the gas on the surface of the water in the siphon is reduced, and bubbles form in the water and continue to rise to the surface until equilibrium of pressures and quantities held in solution is again established, when the bubbles cease to form and the water becomes quiet.

This is the case when the liquid sludge is drawn from the bottom of the Imhoff tank. As soon as the sludge valve is opened the weight of the water above the value forces the sludge up through the sludge pipe, the outlet of which is lower than the surface of the water in the chamber, and the sludge flows out of the pipe charged with gases under pressure. When it reaches the air these gas bubbles expand and loosen the sludge up to a spongy porous condition. The mass is sticky, at first, and it apparently stiffens up, on the sludge draining beds, with the spaces formed by the gas bubbles preserved in the form of pores and open spaces. This greatly facilitates the process of drying, allowing the water contained in the liquid sludge to drain out so freely that ordinarily the sludge can be handled with shovels, like moist soil, a few days after being discharged upon the beds.

35 Last July I visited the plant at Recklinghausen, which treats the sewage of 26,000 people, two days after sludge had been discharged upon the beds from one of the tanks, and it was then dried out so that cracks covered the surface; it was shoveled from the beds the next day and wheeled in push-cars to the dump close at hand. I remained about the plant for some time examining the works, the character of the incoming sewage, the effluent from the works, the fresh sludge drawn from the sludge chamber at my request, the partially drained sludge on the sludge beds, the water draining from the sludge beds, the channel that had been receiving this water for several years, and the piles of sludge that had been removed from the beds in the past, and I could not find any odors about the place, except the smell of new mown hay that was being cut in fields several hundred feet away. This plant had been in continuous operation since the Fall of 1905. A photographic view of the Recklinghausen plant is given in Figure 3.

I visited the works when they were being operated under ordinary every day conditions, and not in anticipation of visitors, having gone

there without appointment. My visit was unexpected until I called upon Dr. Imhoff at his office in Essen and asked to be allowed to go down to the plant at once. The works were then receiving the sewage of about 26,000 people and was hemmed in with shrubbery on a piece of ground which seemed to be not over an acre in area. No attempt is made there to treat the sewage further than by the tanks, the effluent from which is conducted to an open concrete lined channel leading down, eventually, to the Rhine.

The sludge accumulations at this plant, after five years of operation, were insignificant in volume, as farmers in the vicinity come and take it away, paying a small price per load for it. I doubt if its manurial value is high, but its spongy, light nature makes
36 it useful for plowing into heavy soils to render them more
porous and more easy of cultivation.

Sprinkling Filters.

From the Imhoff tank the sewage will be conducted to a series of automatic flush tanks, which will discharge the sewage intermittently in a spray over the surface of the filters.

The filters will be built in beds with concrete floors draining to a general collecting channel leading to the secondary settling tanks. The filters will be built up of coarse gravel, or stones, from about 1½ to 2½ inches in size, and thoroughly underdrained with special tiles to permit the free passage of air entirely through the beds from top to bottom.

Such filters, when the rate of operation is properly adjusted to the character of the sewage, the depth of the filtering materials and the areas of the beds, will change the organic matters in the sewage to a condition not subject to subsequent putrefaction. When the sewage sprayed upon the filters is fresh no offensive or objectionable odors result, but when septic or rotten sewage is sprayed into the air the sulphuretted hydrogen and other gases escape, and may be carried by the winds for some distance, and create very offensive conditions, particularly in the immediate neighborhood of the plant.

The processes which go on in sprinkling filters, when properly designed and operated, produce no odors, as no slow decomposition goes on in the beds. The action is rapid and is brought about in the thin films of sewage flowing slowly over the surfaces of the stones in complete contact with the air, and the effluent from the filters, while more or less muddy in appearance, has no smell and will stand for a long time as inoffensive as ordinary gutter water in the streets after a rain. A small plant which I built last
37 year from the Pennsylvania Chautauqua Grounds, at Mt.
Gretna, along lines somewhat similar to those proposed herein for Orange, Montclair and East Orange was shut down for the season during the early part of September, but the settling basins which had received the effluent from the sprinkling filters all summer were left standing full. I visited the works after this water had been standing for two weeks exposed to the sun and air, and it was then clear, without odor and like ordinary pond water, support-

ing on the surface a growth of green algae, and showing no signs of gray sewage fungi either in these basins or the channels leading from the sprinkling filters, and no odors were detectable about the filters. Stones dug up from some distance below the top of the filter had an odor such as if it had been just dug up from the ground; all traces of odors of putrefaction were absent. I am informed by people who repeatedly saw the plant in operation during the hot summer weather that there was no odor about the place except where a leaky valve from one compartment of the sludge chamber allowed a continual escape of a small amount of decomposing sludge. This was so small that the odor could not be noticed except in the immediate vicinity of the sludge bed upon which it flowed.

The Pennsylvania State Board of Health requires daily reports of the operation of this plant, and these show that no sample collected during the time the plant was in operation showed putrescibility when kept in stoppered bottles for 5 days, the stipulated time for the test. The superintendent kept several samples for much longer times, for his own information, one for two weeks, and it was still stable when he was obliged to throw it away for lack of bottles.

Secondary Settling Basins.

After passing through the sprinkling filters the sewage
38 will go to the secondary settling basins or Imhoff tanks for the deposition of the suspended matters draining from the filters. The tanks would be built with much smaller sludge compartments, than the primary tanks and the deposits taking place therein would be pumped back, as required, to the primary Imhoff tanks, by a small pumping plant.

Machinery and Chemical House.

At a convenient location, probably near the primary and secondary Imhoff tanks, there will be a house containing the pumps for pumping the deposits which gather in the secondary Imhoff tanks to the inlet channel leading to the primary Imhoff tanks. The accumulations in these secondary tanks will be pumped out, as required, and after complete digestion in the primary Imhoff tanks be discharged upon the sludge beds. The service required of the pumps will be intermittent, and their period of operation short, so that elaborate machinery will not be required. The pumps could be driven by electric current, if this could be conveniently secured, or by gasoline engines.

In this house would also be located tanks for making up the necessary chemical solutions and devices for regulating the amounts to be used in accordance with the necessities of the case. Pipes from the house would lead to the various points where the chemicals would be introduced into the sewage.

Water Supply.

A supply of clean water will be essential at the plant for keeping the place clean and for making up the chemical solution. Water

may be had at this point by a connection with street mains about one-half a mile away, or, if preferred, an independent supply can be put in, taking water from the ground by means of a deep well, or a filtered supply sufficient for the needs of the plant could
39 be taken from the river. There would not be a great deal of
difference in the cost of these methods, of getting a water supply.

Superintendent's Residence.

It will be advisable to have a well appointed house for the residence of the superintendent of the plant, who should be a man of experience and ability. It is possible that one of the houses now located on the site proposed for the works could be utilized for this purpose after remodeling. I have, however, included in the estimates of cost a sum sufficient to erect a new residence with proper water supply and plumbing.

General Maintenance of the Works.

After the works are completed it will be essential that not only the disposal plant, but also the trunk sewer and all the sewers in the towns of Orange, Montclair and East Orange be kept clean and in good repair in order that the sewage may be fresh when it arrives at the disposal works. To accomplish this end I would strongly recommend that the three cities appoint a commission to have charge of the construction of the disposal works and connecting sewers, and, after the works are built, to have charge of the operation of the process of purification and also of the maintenance and cleaning of the sewers in each of the three towns, as well as the main outfall sewer leading to the works.

The reason for this recommendation is that even though the disposal plant may be all that could be desired in the matter of design and construction, the superintendent of the disposal works might be greatly embarrassed if, through the neglect of any of the towns to keep the local sewers in repair, and properly clean, foul smelling sewage might arrive at the plant and give rise to disagreeable odors in the vicinity of the plant. If the entire sewerage works of the three towns are under the direction of a joint committee who
40 holds the superintendent of the disposal works responsible for
their inodorous operation there would certainly be no odors detectable at the plant after it has once been put in proper and successful operation.

Estimates of Cost of Construction and Operation.

Based upon the data regarding the quantity of sewage to be treated and the general type of plant above described, I estimate the cost of construction to be as given in Table V.

Table V.

Estimated Cost of Constructing Sewage Disposal Works for Orange, Montclair, and East Orange (Including 15% for Engineering and Contingencies).

Population to be Provided for in First Installation, 133,000 (Estimated to be Reached by 1925).

Items.	Proportion of total cost of construction to be charged to each city on the basis of maximum rate of sewage flow in 1940.			Total Cost.
	Orange. (31.6%)	Montclair. (32.0%)	East Orange. (36.4%)	
Land for disposal works....	$39,500	$40,000	$45,500	$125,000
Joint sewers:				
From plant to junction of East Orange sewer.......	36,340	36,800	41,860	115,000
From East Orange sewer to junction of Orange and Montclair sewers	19,276	19,520	22,204	61,000
Purification works, including grit chambers, Imhoff tanks, sprinkling filters, secondary tanks, machinery and chemical house, water supply, sludge beds, piping connections, superintendent's house, grading, planting, etc.........	259,120	262,400	298,480	820,000
Totals	$354,236	$358,720	$408,044	$1,121,000

When the capacity of these works shall have been reached,
41 additional filters, tanks and sludge beds will be necessary. As these will not be required, however, for many years, the money necessary for their construction would not have to expended at the present time and the cost of such extensions, therefore, when required would be represented by the present worth of the money. The probable cost of these extensions would be about $188,000, but deferring the construction for 14 years (1911 to 1925) would give a present worth, interest at 4%, of $109,000.00, which, with 15% added, would be about $125,000.

The final cost of construction, therefore, for a population of 181,000, which is estimated to be reached by 1940, with the relative costs distributed to the three towns in the same ratio, as above, would be as given in Table VI.

Table VI.

Items.	Orange. 31.6%	Montclair. 32.%	E. Orange. 36.4%	Total.
Cost of first installation of works, as above..........	$354.236	$358,720	$408,044	$1,121,000
Present worth of new extensions in 1925, to serve until 1940	39,500	40,000	45,500	125,000
Totals	$393,736	$398,720	$453,544	$1,246,000

The annual cost of operating and maintaining the works would be made up of the interest on the cost of building the works, an allowance to provide for a sinking fund to retire the bonds, an allowance to cover the depreciation of the works, the salaries paid for labor, and the cost of fuel, chemicals and general supplies.

In the following estimates I have calculated the interest at 4½ per cent. and the sinking fund at 2 per cent. of the cost; the depreciation amounts are based on annuities sufficient to replace the perishable parts of the works at the end of their assumed usefulness; the items for labor include a superintendent and ten men,
42 who are to have charge of the works and the maintenance of the sewers in proper sanitary condition. The items of fuel, chemicals and supplies are based on the quantities of each which I estimate will be necessary. On the above basis the annual cost of operation would be as given in Table VII.

TABLE VII.

Annual Cost of Operation and Maintenance for a Population of 133,000.

(Estimated to be Reached by 1925.)

Items.	Orange.	Montclair.	East Orange.	Total.
Interest at 4½%	$15,941	$16,142	$18,362	$50,445
Sinking fund at 2%	7,085	7,174	8,161	22,420
Depreciation	790	800	910	2,500
Labor	3,160	3,200	3,640	10,000
Fuel, chemicals, etc.	3,160	3,200	3,640	10,000
Totals	$30,136	$30,516	$34,713	$95,365

For a Population of 181,000.

(Estimated to be Reached by 1940.)

Items.	Orange.	Montclair.	East Orange.	Total.
Interest and sinking fund	$25,593	$25,917	$29,480	$80,990
Other items	8,535	8,643	9,832	27,010
Totals	$34,128	$34,560	$39,312	$108,000

For the purpose of showing the relative costs of constructing and operating the plant recommended with the costs to the three cities under the plan proposed by the Passaic Valley Sewerage Commission in their report of 1908, I have arranged, from the data given in that report, the costs of construction, as given; and the annual costs of operation, with interest and sinking fund at 6½ per cent. and the other operating costs in the proportion of the use these towns would make of the sewer (as stated in the report) to the total capacity of the sewer, or, in the ratio of 37 to 360. This gives a cost
43 of $124,567 for interest and sinking fund and $29,000 for the other items, or a total, by 1940, of $153,567.

On these bases, the costs of construction of works sufficient for the population to be expected by 1940 would be as follows:

Estimated Construction Costs to Orange, Montclair, and East Orange of Joining in the Passaic Valley Sewer Project.

Cities.	Orange.	Montclair.	East Orange.	Total.
Costs	$418,890	$600,649	$896,871	$1,916,410

Estimated Annual Costs to Orange, Montclair, and East Orange of Joining in the Passaic Valley Sewer Project.

Cities.	Orange.	Montclair.	East Orange.	Total.
Fixed Charges	$39,363	$39,861	$45,343	$124,567
Other Items	9,164	9,280	10,556	29,000
Totals	$48,527	$49,141	$55,899	$153,567

A comparison of these figures with those for the plan recommended herein shows that it will cost the three cities nearly $670,000 more to join in the Passaic Valley Sewer project than to build a local disposal plant, and nearly $50,000 per year more to meet the necessary operating expenses of the Passaic Valley Sewer than of the plant recommended.

General Summary.

The plant recommended in the foregoing description, with extensions about 1925, will provide for the purification of the sewage of Orange, Montclair and East Orange until the population of these towns shall have reached about 181,000 people, which, I estimate, will be by 1940. All parts of the first installment of the works would be built to take care of a population of about 133,000
44 people except the sewers leading to the plant, which should have capacity sufficient for the population that will be reached by 1940. In the estimates of cost the sewer from East Orange is not included for lack of data as to its course. I have satisfied myself, however, that a sufficient head would be available, from the East Orange town line to the junction with the trunk sewer, to permit of the conducting of the East Orange sewage to the plant in a sewer having a self-cleansing grade.

If maintained with average care, and with an understanding of the nature of the processes to be carried out, and the proper methods of caring for the different portions of the works, the plant should prove a success in every way, and be devoid of objectionable features. The works will be situated in the low ground lying back from the Yantecaw River, and would be surrounded by hills rising up rather steeply from the valley to a height from 50 to 100 feet above the plant. On all sides except at one small corner, the tract of ground is covered with large trees that will hide it from view from the roads traversing around the district. The nearest houses to the plant at

present, except those situated on the tract where the works will be built, are about 1,000 feet away, and there are but two or three of these, and they lie in a position where the prevailing winds will blow towards the plant. By purchasing the tract of land outlined and preserving the trees thereon, and improving the landscape features of the situation by planting trees, shrubbery and flowers, the works could be made very attractive, and would become a centre of much interest for visitors.

There would be no odors connected with the spraying of the fresh sewage upon the sprinkling filters, and none connected with the handling of the sludge from the Imhoff tank, judged by the experience that has been had at other places dealing with stronger sewages of the same general character.

45 The effluent from the plant would go into the Yantecaw River, at all times, in better condition than the waters of the river, and would contain nothing that would injuriously affect any uses to which the water would properly be put for manufacturing or trades uses, or for its enjoyment in any proper way. The discharge of this effluent into the river would not cause the water to become foul, even though several times as great in volume as the river water during dry weather; it would, in fact, be a decided advantage to the river, and to the parties along the stream below, to have the additional flow during dry weather. On the other hand, during flood flows the increase due to the discharge of the effluent in the river would not perceptibly increase flood heights.

As to the absence of nuisance around installations of properly designed Imhoff tanks the best evidence is to be found in and around the City of Essen, Germany, where numerous such plants are situated in densely populated districts. By reference to Figure 1, which is a photograph of the Essen-North plant, it will be seen that directly back of the works is a row of large buildings, several stories in height. These stand about 500 feet from the tanks treating the sewage from 180,000 people, and are high class apartment houses. Figure 3 shows the plant at Recklinghausen, which receives the sewage from 26,000 people. This little plant stands on an area considerably less than an acre in extent, the area of the tanks being 0.05 acre and of the sludge drying beds 0.10 acre. The house close beside the plant is the residence of the superintendent of the works. On the opposite side of the works from the superintendent's house and, as I recollect the location, not more than 500 or 600 feet away, is a very fine detached residence; others are located around the same general neighborhood at various distances from the works, as can be seen in Figure 4. No complaint has ever
46 been made of odors at this plant, nor could I learn of anyone living in the vicinity who had found anything to object to about the works.

Figure 2 shows the sludge beds of the plant at Bochum, which receives the sewage from 150,000 people. High class residences surround the works, those shown being 400 to 500 feet away from the sludge beds.

At the time of my visit, when fresh sludge was drawn from the

tanks at my request, when freshly drawn sludge had been drying upon the sludge beds close beside the tanks for two days and when piles of dried and partially dried sludge were scattered about, a few hundred feet below the works, I could detect no odors about the place arising from the works or their operation. A view of the sludge beds at the Recklinghausen plant is given in Figure 4, and of those at Buchum in Figure 2. The houses shown near the sludge beds at Bochum are about 400 to 500 feet away.

Regarding the sprinkling filters, there is less definite information as to their inodorousness than about the Imhoff tanks. Unfortunately, all the large installations of sprinkling filters which I have visited are receiving septic or rotten sewage, and at most of these, though not all, there was more or less odor detectible at distances of from 200 feet to one-half mile, or more, depending upon the humidity, temperature, direction of the wind, and rottenness of the sewage. There are one or two plants in Europe of moderate size, which are handling fresh sewage, and in these the experience has been similar to the Mt. Gretna plant, in that the fresh sewage has not caused any odors at the sprinkling filters. Another curious circumstance is that at all these plants handling fresh sewage it has been noted that the small flies which are so abundant around most sprinkling filter plants have not, so far, appeared.

It is not necessary, in this report, to enter into a discussion
47 of the chemical and biological aspects of the treatment proposed herein, as I believe that you are more interested in securing my professional judgment as to the general satisfactory condition of such a plant.

It is my judgment that there will be no difficulty in building and operating the plant recommended, in such a manner that it will not produce disagreeable odors at the plant, or in its vicinity, or along the Yantecaw Valley; or cause the Yantecaw River to be less desirable, at any time for any use to which it can now be put; or in any measurable degree increase the heights of floods in the river.

Respectfully,

JAMES H. FUERTES

(Here follow figs. 1 to 5, marked pages 48 to 52, Complainants' Exhibit No. 137.)

Exhibit-137

Fig. 1. Imhoff Tanks at Essen-North (Germany)
Population 180,000
Note Proximity of Dwellings.

Exhibit 137

Fig. 2. Sludge Beds at Bochum (Germany)
Population 150,000
Area of Beds—0.6 of an Acre.

Exhibit 137

FIG. 3. Imhoff Tanks at Recklinghausen (GERMANY)
POPULATION 30,000
Note Dwelling in Background

Exhibit 137

Fig. 4. Sludge Beds at Recklinghausen (Germany)
Area of Beds—0.1 of an Acre.
Beds are Located Between Tanks and Dwelling.

Exhibit 137

FIG. 5. Screens and Grit Chamber at Essen-North (GERMANY).

THE PEOPLE OF THE STATE OF NEW YORK,
COMPLAINANTS,

vs.

STATE OF NEW JERSEY ET AL.

COMPLAINANTS' EXHIBIT No. 138.

Showing Estimated Relative Pollution of Newark and Upper New York Bays Under Different Plans of Sewage Disposal.

JAMES D. MAHER,
Commissioner.

Complainants Exhibit No. 138
James D. Maher
Commissioner

ESTIMATED RELATIVE POLLUTION OF NEWARK AND UPPER NEW YORK BAYS UNDER DIFFERENT PLANS FOR DISPOSING OF THE SEWAGE OF THE PASSAIC VALLEY DISTRICT.